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Carbon Monoxide Intrusion in Sustained-Use Vehicles

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16. ABSTRACT

Section 226 of the Clean Air Act Amendments of 1977 directed the USEPA to perform a study of carbon monoxide (CO) exposures in the passenger area of sustained use vehicles, i.e., buses, taxis, and police cars. A field investigation of vehicle CO levels in two metropolitan areas was conducted. Study objectives were to determine if CO concentrations in the passenger area of sustained-use vehicles is a health concern; to identify conditions and vehicle types conducive to high interior CO exposures, and intrusion mechanisms for such vehicles; and to recommend steps for identifying hazardous vehicles/driving conditions and for reducing CO exposures.

Over 1,000 vehicles were tested. In over 50% of vehicle trips checked by personal samplers, the average CO concentration exceeded the National Ambient Air Quality Standard of 9 ppm over 8 hrs. In 5% of the cases, the OSHA standard of 50 ppm average for 8 hrs was exceeded. Actions for reducing CO intrusion problems are discussed.

Results affirm that fixed station monitors do not accurately assess CO exposure for individuals.

CO was measured with passive dosimeters, active personal samplers, and continuous electrochemical analyzers; a tracer gas detection system was used to identify intrusion pathways.

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by

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NOTICE

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PREFACE

Section 226(a) of the 1977 Clean Air Act Amendments requires a study of carbon monoxide intrusion into sustained-use motor vehicles, such as school buses, taxis, and police vehicles. On April 25, 1979, the Environmental Protection Agency, jointly with the Department of Transportation, transmitted to the Congress a report on the first of a two-phased study of carbon monoxide intrusion. This consisted of a literature survey and the results of a pilot study of 37 vehicles.

The present report, prepared exclusively for EPA, includes the results of an extensive study of more than 1,000 vehicles. Exposure levels have been measured, and major sources and pathways identified. Available methods of monitoring and testing vehicles for the presence of carbon monoxide were tested and evaluated in the study, and their relative costs and advantages were analyzed.

Not addressed in this report, however, are two elements specifically mentioned in section 226(a) of the statute. Among other things, this section directed EPA to do a study of health effects of the CO levels encountered by the driver and passengers in sustained-use vehicles. Considerable reliable health effects information has been continually accumulating on this subject for several years. Much of it is contained in EPA's criteria documents on carbon monoxide.* Rather than duplicate work already done, EPA concentrated on determining exposure levels. These levels, together with criteria document data, constitute a complete set of the information required to estimate probable health effects associated with the observed exposure levels.

A second requirement in section 226(a) was to compare the costs and benefits of alternative strategies for attaining and maintaining acceptable levels of carbon monoxide in the passenger area of such vehicles. The Agency decided at the beginning of the research project to use existing and ongoing cost-benefit analyses on CO as the basis for a comparison. However, no detailed comparison was prepared by the Agency.

*_Air Quality Criteria for Carbon Monoxide_. U.S. DHEW. Washington, D.C., March, 1970. AP-62.

Air Quality Criteria for Carbon Monoxide. U.S. EPA. Washington, D.C., October, 1979. EPA-600/8-79-022.

ABSTRACT

This field investigation was begun with the overall objective of measuring carbon monoxide (CO) levels in the passenger area of sustained-use vehicles (principally buses, taxis, and police cars). In addition to the major objective, attempts were made to identify traffic and environmental conditions, vehicle types, and operating conditions which could lead to relatively high interior CO exposures. Further, researchers wanted to identify major intrusion mechanisms for such vehicles and to evaluate methods for quickly identifying possible hazardous vehicles.

CO was measured with passive dosimeters, active personal samplers, and continuous electrochemical analyzers. A tracer gas system was used to identify intrusion pathways.

Over 1,000 vehicles were tested in two cities. All vehicles were in use as part of a working fleet at the time of testing. However, because of the lack of nationwide coverage, it is not possible to extrapolate the findings of this study to the nation as a whole. In over 50% of the 132 vehicle trips checked by personal samplers, the average CO concentration exceeded the National Ambient Air Quality Standard of 9 ppm over 8 hours. In 5% of the cases, the OSHA standard of 50 ppm average for 8 hours was exceeded.

Sources of fugitive emissions and intrusion pathways were identified in all vehicles which had elevated CO levels. Carbon monoxide was found to be transmitted to the passenger area of police vehicles and taxicabs through the trunk and the rear seat and parcel shelf. Principal CO sources were leakage from the rear of the exhaust system or the actual tailpipe exhaust. In addition, some vehicles with catalytic converters had high CO levels. School buses exhibited severe intrusion leaks at the rear emergency door seal, the heater or windshield hose, and the fittings along the exhaust system.

This report was submitted in fulfillment of Contract No. 68-02-3220 by Science Applications, Inc., 1801 Avenue of the Stars, Los Angeles, California, under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period of March, 1979, to June, 1979, and work was completed as of November 15, 1979.

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SECTION 1

INTRODUCTION

Concern has been expressed in recent years over the possibility that motor vehicle passengers are exposed to potentially harmful levels of carbon monoxide (CO). The health effects of carbon monoxide are relatively well characterized, and both ambient and occupational exposure limits have been set by federal and state agencies. Relatively little is known, however, about the concentrations to which riders of sustained-use passenger vehicles (principally buses, taxis, and police cars) are exposed. Section 226 of the Clean Air Act Amendments of 1977 directed the U.S. Environmental Protection Agency (USEPA) to perform a study of these exposures. In 1978, a literature review, evaluation of CO monitoring devices, and a pilot measurement study were performed for the USEPA (Ziskind, et al., 1978). The present work consisted of a full field investigation of CO levels in school buses, taxis, and police cars in two metropolitan areas.

The objectives of the field study were:

1. To obtain sufficient data to determine whether CO concentrations in the passenger area of sustained-use vehicles may be of potential health concern;

2. To identify traffic conditions, vehicle types, and operating conditions which could lead to relatively high interior CO exposures; and,

3. For vehicles having high observed CO levels, to identify major intrusion mechanisms.

Section 2 contains the conclusions of this study. Experimental procedures and results are presented in Sections 3 and 4, respectively. The following three key program topics are discussed in detail in Section 5: (a) experience with measurement procedures and instrumentation; (b) intrusion mechanisms; (c) the relationship between fixed site monitoring data and passenger exposure. In addition, quality assurance procedures are described in Appendix B.

SECTION 2

CONCLUSIONS

Since the vehicles were selected in a non-random fashion from only two cities, the conclusions reported below apply only to the vehicles actually measured. Consequently, data from these vehicles should not be extrapolated to the national scene.

Conclusions from the results of this study were drawn in three general areas:

I. The adequacy of the research protocol and instrument performance;

II. The distribution of CO exposure in the vehicle study population; and,

III. The mechanisms underlying intrusion of CO into vehicle interiors.

The following conclusions were reached:

1. The sequential use of passive stain tubes, personal samplers, and continuous analyzers was successful in developing a statistical base with which to determine the distribution of CO exposure in the test population.

2. An improvement in the measurement sequence would be to increase the frequency of placing stain tubes side-by-side in vehicles in order to improve precision.

3. In greater than 50 percent of the 132 vehicle trips measured by personal sampler, the average CO concentration exceeded the National Ambient Air Quality Standard of 9 ppm over 8 hours. Typically, the CO level measured inside or immediately outside the vehicle significantly exceeded the value recorded by the nearest fixed site monitoring station. Vehicle self-contamination does not appear to be the cause of this disparity. Rather, it is postulated that the proximity of the vehicle to the emission sources accounts for the difference between vehicle and fixed site monitor concentrations.

4. The Occupational Safety and Health Administration (OSHA) standard of 50 ppm average over an 8-hour period was exceeded in 5 percent of the cases, as measured by personal sampler.

5. The three-stage instrumentation sequence, plus a more detailed vehicle inspection, continuous analyzer examination, and gaseous tracer testing enabled the identification of the source of fugitive emissions and intrusion pathways in all vehicles which had elevated CO levels. In addition, all vehicles which had either elevated CO levels or interior concentrations in excess of the exterior over a significant time fraction of a trip, were found to have both exhaust system leaks and pathways through to the passenger areas. Conversely, it was not always true that the presence of an exhaust system leak and an intrusion pathway resulted in elevated interior levels of CO.

6. Total mileage, age, manufacturer, or mileage since last tuneup are not useful for identifying high-exposure vehicles. Rather, only after a careful inspection for intrusion pathways and confirmation of the existence of CO leakage sources is it possible to demonstrate a relation between sources and high exposures. In certain cases, however, it was possible to identify an intrusion mechanism (source and/or pathway) which was common to all high-CO vehicles of a given type. Knowledge of this characteristic may be useful for future fleet observation and maintenance.

7. The greatest potential for accumulation of CO within a vehicle (over and above the immediate external concentration) exists when doors, windows and vents are all closed. Therefore, the combination of elevated winter ambient CO levels and concomitant vehicle closure pose the greatest potential hazard.

8. Carbon monoxide was observed to be transmitted into the passenger area of police vehicles and taxicabs through the trunk and the rear seat and parcel shelf. The principal CO sources were leakage from the rear of the exhaust system or the actual tailpipe exhaust. This pathway was observed more frequently than had been expected. Other important leak areas were the vertical inlet seal and the engine exhaust manifold.

9. Some vehicles with catalytic converters had high CO levels. Leaks in the exhaust systems of these vehicles were severe and of great potential importance. These leaks were not associated with the catalytic converter itself, but instead were leaks located at the junction points of the exhaust system. Since some of these leaks are located near the driver, transmission of CO from these sources into the vehicle interior may be of some consequence. Heat, vibration, and material degradation are suspected causes. It is not possible to evaluate the scope of this problem without additional data; however, consideration must also be given to the importance of these leaks on vehicles equipped with catalytic converters, as sources of ambient carbon monoxide. The vehicle exhaust, after passing through the catalytic converter, may meet the emission standard. However, sizable leaks prior to the converter can contribute levels of pollutants higher than expected.

10. Among school buses with excessive interior CO levels, severe intrusion leaks were most often noted at the rear emergency door seal (13 leaks in 14 buses tested), the heater or windshield water hose (11 of 14), and the fittings along the exhaust system, particularly the manifold to head pipe (11 of 15), and the muffler tailpipe (9 of 15).

SECTION 3

EXPERIMENTAL PROCEDURES

SELECTION OF SITES AND PARTICIPANTS

Suitable locations in which to perform this study were considered to be those where (a) elevated ambient CO concentrations were known to be present, (b) stationary monitoring sites would be able to provide data in a usable format for comparison to vehicle measurement data, (c) a sufficient number of test vehicles were identified, and (d) fleet operators had expressed a willingness to cooperate.

Since a number of major cities satisfy these requirements, it was necessary to further define the criteria for city selection, incorporating other factors which will assist in providing the most useful data base for generalizing to the national scene. Specifically, since higher altitude plays a role in aggravating both the vehicle emission factor for CO and also the resultant physiological condition of hypoxia, the Denver area, having satisfied the other criteria, was chosen for testing. The second city chosen was Boston. It was typical of the several eastern cities under consideration and had a well traveled and congested downtown area with many "urban canyons", tunnels, and covered expressways, and a diversity of bus and taxi models.

Cooperating relationships were established with a number of companies and agencies to make available a sufficient number of vehicles for testing. The following groups participated:

Denver Public School District
Jefferson County School District
Cherry Creek School District
Boulder Valley School District
Denver Metropolitan Police
Yellow Taxi - Denver
Colorado State Patrol
ARA Bus Lines
Red Cab Company

Additionally, relationships were established with the cognizant air pollution monitoring agencies in Denver and Boston in order to obtain hourly average CO concentrations at fixed site stations near the routes for which our CO measurements were made. The applicable agencies are the Air Pollution Control Division of the Colorado Department of Health and the Massachusetts

Department of Environmental Quality, which have six and five stations, respectively.

MEASUREMENT STRATEGY

Section 226 of the Clean Air Act Amendments of 1977 requires a study of ". . .sources and levels of carbon monoxide in the passenger area . . ." of sustained-use vehicles. Therefore, it is clear that both the interior concentrations of CO and their causal factors need to be identified and quantified in a statistically significant manner. To obtain this information cost-effectively, a multiphased field measurement program was formulated. The objectives of this testing were to:

- Develop baseline CO concentration statistics for a large number of randomly selected vehicles from specific classes of sustained-use vehicles in normal operation; and, to

- Isolate, identify, and quantify factors of vehicle design, use, physical condition, maintenance, driver or passenger control, and exposure to external conditions which may be associated with elevated interior CO levels.

Four types of instrumentation were employed in sequence: glass stain tube dosimeters, personal samplers, continuous monitors, and, for a select group of vehicles, tracer gas detectors. Figure 3-1 outlines the field measurement program.

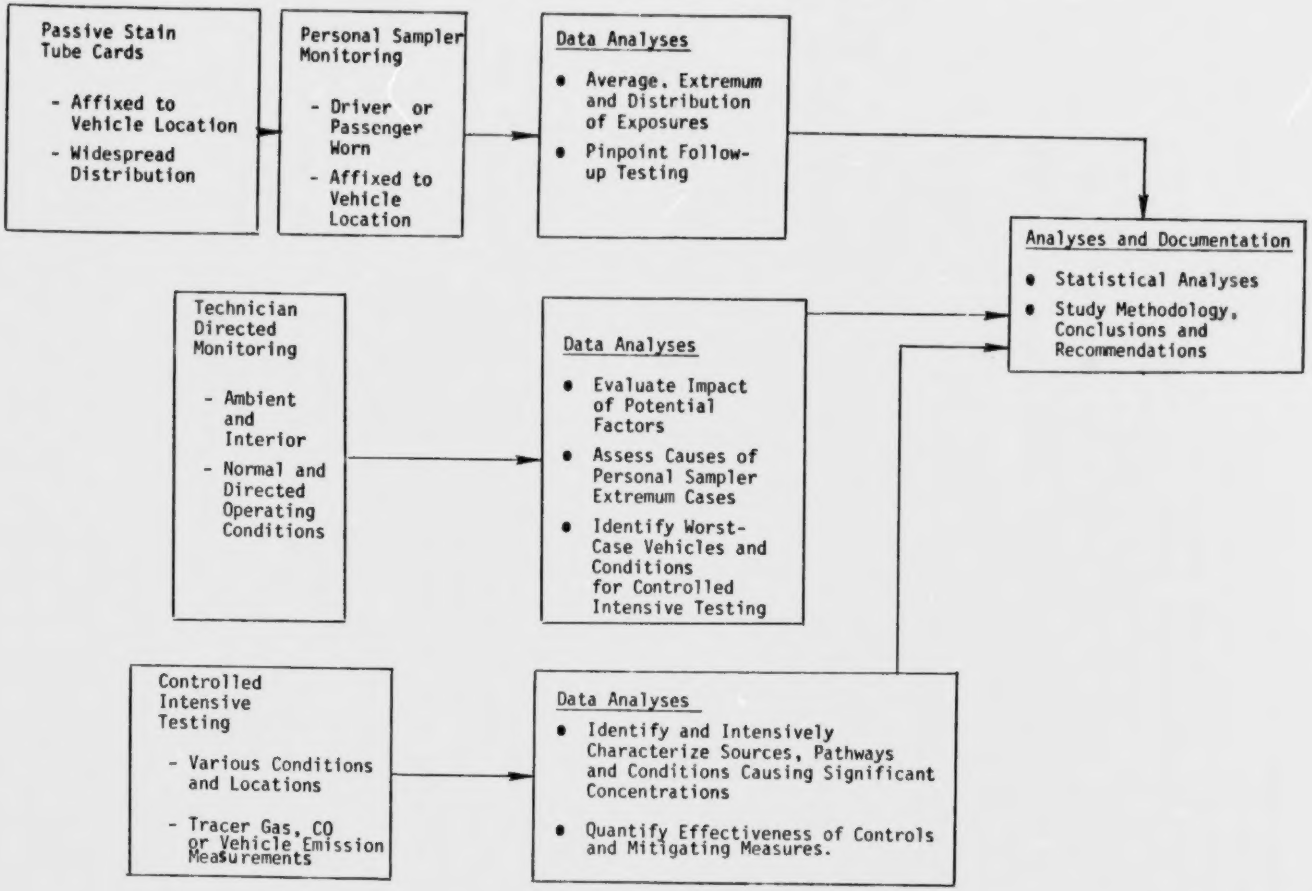
Glass Stain Tube Dosimeters (Stage 1A)

First, a passive cumulative dosimeter in the form of a stain tube mounted on a 3 x 5 inch card was affixed to a reference location in the vehicle. The stain length reading along with the exposure duration yield a cumulative CO concentration over the measurement period. (The method used for calibrating the stain tubes is described in Appendix B.) Such readings were taken on 100 percent of the study vehicle population.

The MSA glass tube indicators were used as follows. The tubes were severed at a prescribed scratch mark, labeled with an identification number, and placed in the vehicle immediately prior to departure. On buses, the primary location was the dashboard or a window area at the driver's head level. The secondary bus location used was the underside of the rearmost accessible seat. For taxi-cabs and police vehicles, tubes were placed on the dashboard on the driver's side. Returns to the school bus depot during the mid-day activity were logged and accounted for with simultaneous depot readings taken by a continuous analyzer.

Information sheets were compiled for each of the vehicles measured by this device. They included physical inspection observations, maintenance information, route data (as appropriate), manufacturer specifications, and other data which would be useful in evaluating measurement results and planning further testing. In certain cases, several cards were simultane-

Figure 3-1 Field Measurement Program Flow


Passive Stain Tube Cards
- Affixed to Vehicle Location
- Widespread Distribution
Personal Sampler Monitoring
- Driver or Passenger Worn
- Affixed to Vehicle Location
Data Analyses
• Average, Extremum and Distribution of Exposures
• Pinpoint Follow-up Testing
Analyses and Documentation
• Statistical Analyses
• Study Methodology, Conclusions and Recommendations
Technician Directed Monitoring
- Ambient and Interior
- Normal and Directed Operating Conditions
Data Analyses
• Evaluate Impact of Potential Factors
• Assess Causes of Personal Sampler Extremum Cases
• Identify Worst-Case Vehicles and Conditions for Controlled Intensive Testing
Controlled Intensive Testing
- Various Conditions and Locations
- Tracer Gas, CO or Vehicle Emission Measurements
Data Analyses
• Identify and Intensively Characterize Sources, Pathways and Conditions Causing Significant Concentrations
• Quantify Effectiveness of Controls and Mitigating Measures.

ously placed in vehicles as part of the quality assurance procedures (see Appendix B) or to measure the distribution of carbon monoxide within the vehicle. Some readings were repeated on separate days to provide additional data and vehicle intercomparison, to check repeatability, and to further examine interrelationships with fixed site monitor readings.

The stain tube readings contributed principally to the first specified program objective, i.e., to develop baseline CO concentration statistics for a large number of randomly selected vehicles. A second purpose was to facilitate the selection of a proper representative test sample for measurement with the limited number of personal sampler and continuous analyzer instruments at our disposal. This was achieved by measuring virtually 100 percent of the vehicles with stain tubes and characterizing each fleet by its distribution of CO concentrations. There was little expectation that the stain tube data would be useful to identify individual mechanisms which influence CO concentration, although individual high-CO vehicles were identified and scheduled for follow-up investigation.

Personal Samplers (Stage 1B)

Personal samplers were used in the next measurement phase. The units each consisted of a dosimeter (Energetics Science® Model 9000) in combination with a Dupont® Model P200 pump. It was desired to sample across a broad range of vehicle types, locations, and other design and inspection parameters. In addition, the results of the glass tube sampler readings were considered in order to select a representative distribution of exposure ranges. Personal dosimeters were issued to drivers immediately before they started their work shifts. The technician first started the pump, zeroed the dosimeter, and then affixed the sampler with the inlet tube near the breathing zone. Drivers were given information sheets and verbal instructions to reinforce the desired standard procedure. In the great majority of cases, only non-smokers were instrumented. The only important exception was for one of the taxicab fleets in which drivers and/or passengers smoked during approximately 90 percent of the runs. Start and stop times, final reading, drivers' approximate locations during the work shifts, and vehicle identification numbers were compiled for each corresponding time period in order to facilitate the determination of total CO exposure and the vehicle-induced contribution.

These instruments provided a more precise measure of personal exposure than the glass tubes and required no subjective judgement, since a digital reader was used. In stage 1B, only the specific route information for the day of testing was added to the information compiled on each vehicle during the Stage 1A (stain tube) measurements. Coincidence between elevated Stage 1A and Stage 1B readings was tested as was the correlation between each category of vehicle information and the dosimeter value.

Continuous Monitoring (Stage 2)

Stage 2 testing employed two continuous reading instruments coupled to a dual channel recorder. Some vehicles were selected for testing because they exhibited high glass tube and personal sampler readings. Also designated for testing were vehicles of specific manufacturers, mileage ranges, configuration, routes, and various other features. A technician was present throughout to direct the testing and record information.

The instrumentation used consisted of Interscan® Model 1146 CO analyzers and dual pen Soltec® Model VP-6723S recorders. Air was sampled from locations outside and inside the vehicle through Teflon® tubes connected to the analyzer input. This arrangement permitted later comparison of interior and exterior levels and identification of conditions under which extreme absolute concentrations and differences (positive and negative) between interior and exterior readings occurred. Comparisons with fixed site station monitor data were also made.

The technician noted the occurrence of particular conditions by placing an alpha-numeric coding on the chart with a corresponding description upon a trip log sheet. Later, this enabled the researchers to know the operating conditions at every instant and to interpret findings. Furthermore, portions of the continuous traces were selected, as appropriate, for computing averages by planimeter techniques. Each measurement sequence lasted several hours; therefore, a large number of operating and external conditions were observed and tracked. During a typical vehicle run of approximately two hours, it was possible to measure CO at all interior locations under the full spectrum of operating conditions.

Finally, for a limited number of specific vehicles, a series of special tests were conducted to ascertain the mechanisms responsible for elevated concentrations of CO found during prior testing. The measurement techniques, approach, and data evaluation are described in Section 3, page 14.

INSTRUMENTATION

In each stage of testing, a different type of CO detection instrument was used. In the initial survey phase, the MSA® CO Dosimeter Model 3 shown in Figure 3-2 was utilized. A summary of its principal characteristics, along with those of the other CO detectors employed in the program, is provided in Table 3-1. Limitations affecting its accuracy include the narrow spacing between stain length indicator marks and the difficulty of discerning the stain migration boundary.

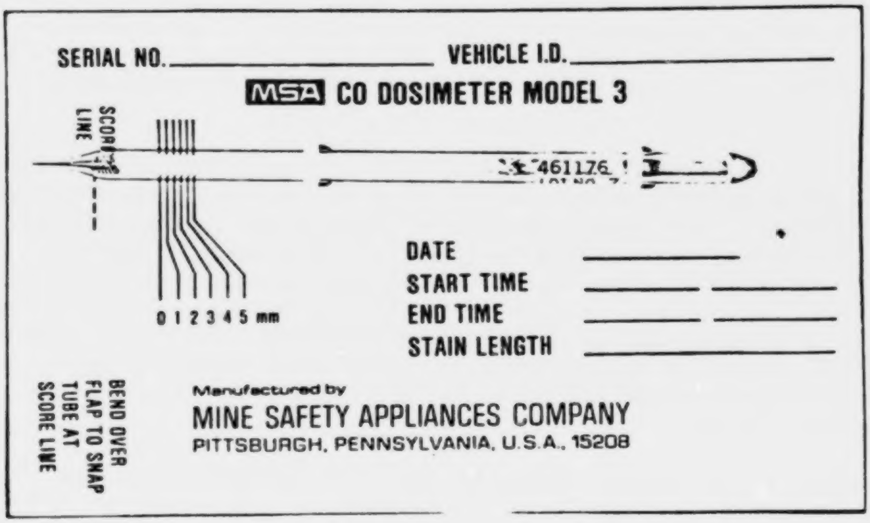
The personal sampler unit consisting of the Energetics® Science dosimeter and Dupont® pump is shown in Figure 3-3. Also shown is a digital display reader. The sampler unit was worn on the person in a manner suitable to the individual's attire. This instrument also produced a cumulative reading of CO exposure. The continuous analyzer, Interscan® Model 1146, and Soltec® dual channel recorder are shown in Figure 3-4. The usual configuration consisted of two analyzers strapped onto a single recorder. Instrumentation for the special testing phase, consisting principally of a sulfur hexafluoride (SF_6) tracer gas generator and detector system, are discussed in Section 3, page 22.

VEHICLE INSPECTION

Information on each vehicle was obtained in order to examine a range of factors which might show a correlation with elevated CO levels. If such

Figure 3-2

Stage 1A Stain Tube Dosimeter



SERIAL NO. ____________ **VEHICLE I.D.** ____________

MSA CO DOSIMETER MODEL 3

SCORE LINE
461176
0 1 2 3 4 5 mm
BEND OVER FLAP TO SNAP TUBE AT SCORE LINE

DATE ____________

START TIME ______ ______

END TIME ______ ______

STAIN LENGTH ____________

Manufactured by

MINE SAFETY APPLIANCES COMPANY

PITTSBURGH, PENNSYLVANIA, U.S.A., 15208

CARBON MONOXIDE VEHICLE INTRUSION STUDY

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La Jolla, California

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Research Triangle Park
North Carolina

Table 3-1

SUMMARY OF THE CO MEASUREMENT/DETECTION DEVICES UTILIZED

CLASS	CUMULATIVE DOSIMETER	CUMULATIVE DOSIMETER	CONTINUOUS ANALYZER
MANUFACTURER	Energetics Sciences, Inc.	MSA	Interscan Corp.
MODEL	Ecolyzer 9000	CO Dosimeter Model 3	CO Analyzer Model 1146
APPROXIMATE COST	$450 and Reading Kit $960	~ $1 (in quantity)	$1175
MEASUREMENT PRINCIPLE	Electrochemical	Stain Tube	Electrochemical
TYPE OF MEASUREMENT	Cumulative	Cumulative	Continuous
RANGE	0-1638 ppm-hrs	~ 35 ppm x 1 day, x 7 days	0-50; 0-100*
ACCURACY	± 15% of reading	± 25%	± 2% F.S.
SENSITIVITY (M.D.L.)	1 ppm-hr	35 ppm	1% of F.S.
ZERO STABILITY	0.5 ppm/day	--	± 1% F.S./day
RESPONSE	< 30 sec to 90%	--	90% in 20 sec.
SIZE	18.4 in^3	3" x 5" x 1/4"	7½" x 6" x 11½"
WEIGHT	9 oz.	1/2 ounce	8 lbs
POWER	Battery	None	Rechargeable Battery
TEMPERATURE RANGE, ^oC	0-40	0-40	-7-38
HUMIDITY RANGE, %R.H.	0-100	0-95	0-100
POSITION SENSITIVE	No	No	No
VIBRATION SENSITIVE	No	No	No
PRINCIPAL INTERFERENCES	C_2H_2, C_2H_4	H_2, H_2S, C_2H_4	Some Unsaturated HC
CALIBRATION	Span Gas	None	Span Gas
COMMENTS	Humidification Required	Avoid Direct sunlight	* Other Ranges Available

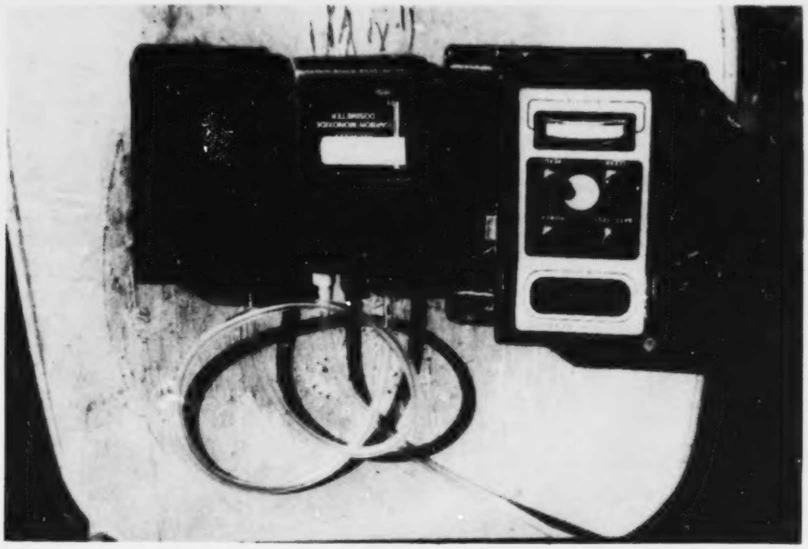

Figure 3-3. Stage 1B Digital Reader, Personal Dosimeter and Pump

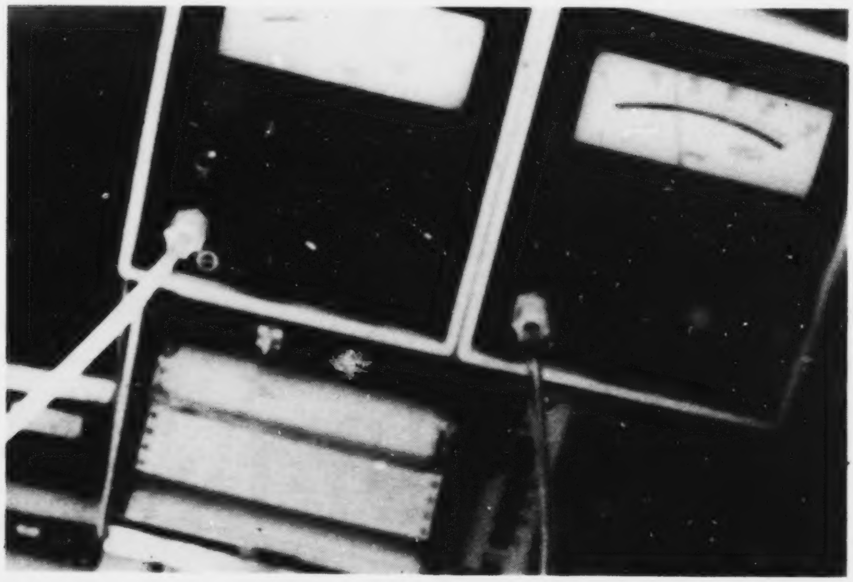

Figure 3-4. Stage 2 Instrumentation - Continuous Analyzers and Dual Channel Recorder

relationships could be established as statistically significant, such parameters could be used as predictive tools for identifying corrective actions to be taken in order to reduce CO concentrations. The vehicle inspection forms that were used are shown as Table 3-2. In order to complete these required the physical inspection of each vehicle, the review of maintenance records, and discussions with dispatchers and/or drivers. This information was listed, coded, and presented with CO test data on worksheets of the form given as Table 3-3.* Additional information was recorded such as from item #16 of the Vehicle Inspection Form. Comments such as "noting the odor of exhaust" or "especially heavy traffic" were appended. Codes were devised to indicate the presence or absence of intrusion points, route location, condition of the exhaust system, etc. Monitoring data were also tabulated on these worksheets. Chi square analyses were performed to compare the expected and observed frequency of occurrence of each parameter versus the level of CO concentration measured. This considered, for example, the relationship between CO level as measured by glass tubes and the presence and location of intrusion points such as holes in the floorboard, poor door seals, or poor trunk seals.

Other statistical tabulations made included means and 95% confidence limits. Analysis of variance was made between pairs of fleets and dispatch garages by utilizing t-tests of means.

SPECIAL TESTING

Introduction

A special phase test program was designed and implemented in order to make an intensive evaluation of a small number of selected, sustained-use vehicles. These vehicles had been identified in the earlier testing and screening programs as vehicles with particularly high interior carbon monoxide levels. The general objective was a careful,detailed evaluation of each of these selected vehicles and the source locations (such as exhaust system leaks) and the intrusion pathways responsible for the elevated interior CO levels. In addition, a sequence of tracer gas tests was performed on selected vehicles in order to further delineate intrusion pathways and to show general characteristics of the intrusion process such as the dependence of interior CO concentration on particular source location (specific location along the exhaust system) and on operating mode (idle or on-the-road). The use of a tracer gas (sulfur hexafluoride) allowed the effect of a particular source location to be isolated from other source locations such as other exhaust system leaks, outlets, or other vehicles.

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*Summary worksheets are provided as Appendix C for nearly all of the test data. Readings determined to be invalid due to equipment or operator error were discarded and are unreported. This included, unfortunately, a significant amount of personal sampler results. Problems associated with personal samplers are discussed in the text.

Table 3-2

VEHICLE INSPECTION FORM

(1) DATE ____________________ (2) TIME ____________

(3) FLEET NAME _________________________ (4) FLEET VEH. I.D. NO. ______

(5) TYPE OF VEHICLE (SCHOOL BUS, TAXI, POLICE CAR) ________________________

(6) LOCATION OF DEPOT ____

(7) LOCATION OF ROUTE ____

(8) VEHICLE MAKE, MODEL, YEAR, DESCRIPTION ____________________________
(2-door, 4-door, length of bus, no. of passengers, etc.)
____

(9) ENGINE MAKE, MODEL, DESCRIPTION _________________________________
(Diesel, Gasoline, V8,6)
____

(10) MILEAGE _______________ FROM OVERHAUL _________ FROM TUNEUP _______

(11) ENGINE LOCATION (Front, Rear) _____________________________________

(12) EQUIPMENT, ACCESSORIES AND UNIQUE FEATURES (Turbocharger, Air Conditioner, Forced Air Ventilation)
____

(13) EXHAUST SYSTEM ROUTING AND CONDITION DIAGRAM (Show Couplings and Relationship to Air Vents, Estimate Distances, Indicate Faulty Conditions).

VEHICLE INSPECTION FORM (CONT'D)

(14) POSSIBLE INTRUSION POINTS (List or draw holes in floorboards, poor seals, broken windows, etc.)

(15) CONDITION OF VEHICLE (List points of poor condition in exhaust system and body such as rust, dents, holes, oily coating or soot on the interior)

____

____

(16) OPERATORS COMMENTS ____________________________

____

____

Table 3-3

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: ______________ CITY: ______________ TYPE OF VEHICLE : ______________

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	

The special testing program was performed in two cities, Denver and Boston, and at locations (principally urban) representative of actual vehicle use. Intensive testing utilizing detailed inspection and CO measurement techniques was performed on a total of 16 school buses and 8 police and taxi vehicles. The detailed sequence of tracer tests was performed on a total of 6 school buses and 5 police and taxi vehicles. A summary of the test objectives, procedures, and specialized instrumentation are given in the following sections. Test results and discussion are contained in Section 4, SPECIAL TESTING: OVERVIEW OF DATA COLLECTION AND INTERPRETATION, with the vehicle data compilation in Section 4, VEHICLE CASE STUDIES.

Special Testing Objectives

The primary objectives of the Special Test phase were as follows:

1. To identify CO source locations such as leaks in the exhaust system or improper exhaust outlet locations;
2. To identify potential CO intrusion pathways that may allow CO to enter the vehicle interior;
3. To identify and verify the actual CO intrusion pathways for the vehicles in question and under various operating conditions; and,
4. To perform tracer simulation tests to characterize the relative severity of interior concentration levels as a function of particular source location and operating condition.

Special Testing Procedures

A special testing program was implemented utilizing three basic test procedures described in the following sections. They are described in the general order in which they were carried out, and each of the procedures is complementary to the others. For example, potential source locations and potential intrusion pathways were first identified by inspection procedures. Then, CO monitors were used to identify which potential sources and intrusion pathways are active contributors. And, finally, SF_6 tracer simulated and isolated source contributions at particular locations and verified intrusion pathways by which tracer from that source actually enters the vehicle interior.

CO Source Location Identification--

The first step in this source location procedure was a detailed visual inspection of the vehicle exhaust system. Potential source (leak) locations were identified and noted, such as corrosion, loose connections, black/gray deposits, improper outlet location, etc.

The inspection procedure was then followed with a verification test utilizing a continuous carbon monoxide monitor with sampling line. Each of the potential leak locations identified by inspection as well as all exhaust system connections were checked by placing the sampling line intake adjacent to those locations. Even very small leaks were readily identified in this manner, and the relative severity of the leak could be qualitatively noted by observing the CO monitor response. Characteristic source locations were marked with chalk and photographed. Figure 3-5 illustrates a test vehicle undergoing exhaust system inspection and leak detection.

CO Intrusion Pathway Identification Procedure--

Potential CO intrusion pathways were identified by detailed inspection of all vehicle surfaces and partitions that make up the envelope surrounding the vehicle interior space. The engine compartment was inspected for potential entry points through the fire wall, such as holes, grommets, seals, gaskets, openings for foot pedals, gear shift, etc. A similar inspection was carried out under the vehicle, particularly on the floor pans, the trunk floor, and other potential pathways. The vehicle exterior was checked for potential pathways such as door seals (particularly rear door seals on school buses), fuel filler entries, and specialized entries such as the mounts and wiring for sirens and lights on police cars, lights and signs on taxis, etc. The vehicle interiors were inspected for any visible evidence of intrusion pathways such as openings in fire walls, boots around gear shifts, pedals, emergency brakes, feed throughs for heating lines, controls, and other wiring. On police and taxi vehicles, the interior of the trunk was thoroughly inspected, particularly for holes or corrosion or other places in the trunk floor or envelope where exhaust CO could potentially enter. On most vehicles of the automotive type, partitions between the trunk and the passenger space are rather flimsy and do not provide much barrier to gases.

In addition to the inspections procedure for intrusion pathways, a continuous CO monitor with sampling line was utilized to inspect potential intrusion pathways inside the vehicles while the vehicle was operated at idle condition.

Tracer Test Procedures for Intrusion Pathway Verification and General Characterization of the Intrusion Process--

The tracer tests for each vehicle involved a sequence of 6 individual tests. Each of the 6 tests involved the release of SF_6 tracer gas to simulate a CO exhaust gas release at one of the three following characteristic exhaust system locations:

1. The engine exhaust manifold connection to the exhaust head pipe.
2. A location approximately mid length along the exhaust system, typically near the exhaust pipe to muffler connection.
3. The exhaust system outlet.

For each of these release locations, two individual tests were performed, one under stationary idling conditions and the other under mobile on-the-road

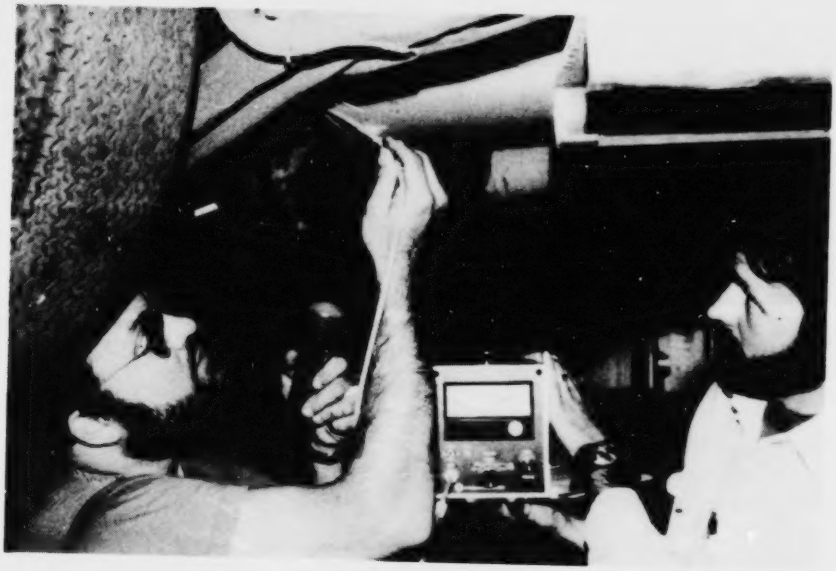


Figure 3-5. Exhaust System Inspection and Leak Detection Utilizing CO Monitor

operating conditions, for a total of six individual tests for each vehicle in the tracer test sequence.

For each of the six individual tests per vehicle, the following measurements were made in the vehicle:

1. Front section of the vehicle interior. Semi-continuous sampling of air at driver breathing level to determine rate at which tracer concentration rises and the steady-state concentration achieved.

2. Rear section of the vehicle (rear section breathing level of buses or mid point of trunk space for automotive vehicles). Semi-continuous sampling to determine rate at which tracer concentration rises and the steady-state concentration achieved.

3. Check use of SF_6 tracer sampling probe to verify whether previously identified potential CO intrusion pathways were indeed the actual pathways for tracer gas released at different points in the vehicle.

All tracer tests were performed with vehicle windows and doors closed in order to simulate the expected worst-case winter type conditions. For each vehicle, the six individual tests were repeated sequentially along the same driving routes and using the same in-vehicle measurement points in order to make the tests as comparable to each other as possible. The basic procedure for each of the six individual tests per vehicle was as follows:

1. SF_6 release system set up at correct metered release rate and the release nozzle fastened on exhaust system at correct release (simulated leak) location.

2. Vehicle interior space thoroughly aired out and uniform baseline SF_6 concentration achieved by driving vehicle with windows and (in case of buses) doors open in an area away from the testing route.

3. Vehicle placed in operation (idle or on-the-road operation) for test conditions with all windows and doors closed.

4. Sampling pump system started with initial sampling in front and rear of vehicle to establish stable pretest baseline.

5. Remote actuation of SF_6 tracer release solenoid at time $t = 0$ to start test.

6. Semi-continuous tracer concentration sampling at front breathing level and rear breathing level (trunk space on automobiles) and sampling of potential intrusion pathways. This sampling procedure continues until steady-state tracer concentrations are achieved at both the front and rear sampling locations.

7. Remote shut-off of tracer release system to end test.

Figure 3-6 shows a test vehicle being readied for the next test in the tracer test sequence. The tracer release system is attached to the rear bumper with injection lines going under the vehicle and fastened to the exhaust system at the three release locations. An electric fan is being used to rapidly clear the trunk space of tracer gas. The tracer detection instrumentation is in the left rear seat. In addition to the driver, two test technicians were required, one in the back seat operating the tracer detection instrumentation and sampling the rear intrusion pathways, and one technician in the front seat sampling the breathing level and the front intrusion pathways.

Special Test Instrumentation

The CO source location identification (Section 3, CO Source Location Identification) and CO intrusion pathways identification (Section 3, CO Intrusion Pathway Identification Procedure) procedures utilized continuous CO monitors as instrumentation. These monitors were the same Interscan Monitors utilized in Stage 2 of the overall program and are described elsewhere in this report. However, the tracer test procedure (Section 3, Tracer Test Procedures...) required the design, preparation, and calibration of specialized instrumentation and hardware to achieve the test results. This tracer test instrumentation involved basically three systems:

- The tracer release system;
- An air sampling system; and,
- The continuous tracer detection instrumentation.

The tracer release system consists of the following principal components:

1. A set of interchangeable tracer gas storage cylinders with four SF_6 concentrations at two decade increments from 1 ppm through 100%.
2. Three release metering valves and rotameters, manifolded in parallel to give an overall release rate range from 0.002 to 25 liters/minute.
3. An on/off solenoid valve wired so that tracer release could be started or stopped from inside the vehicle while driving.
4. Sampling lines and miscellaneous hardware to provide tracer release at the three desired simulated CO release locations.

Figure 3-7 shows the special SF_6 release system attached to vehicles for on-the-road testing.

The sampling system inside the vehicle consisted of portable battery powered sampling pumps with sampling lines arranged to provide the front and

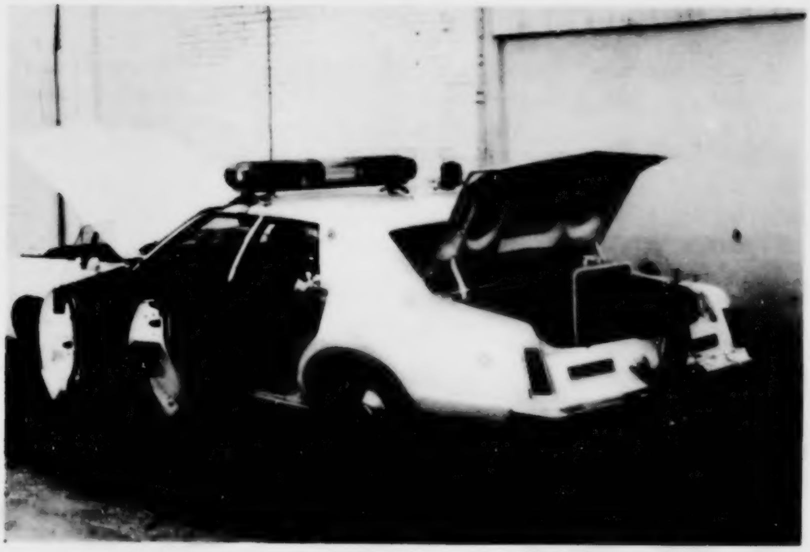
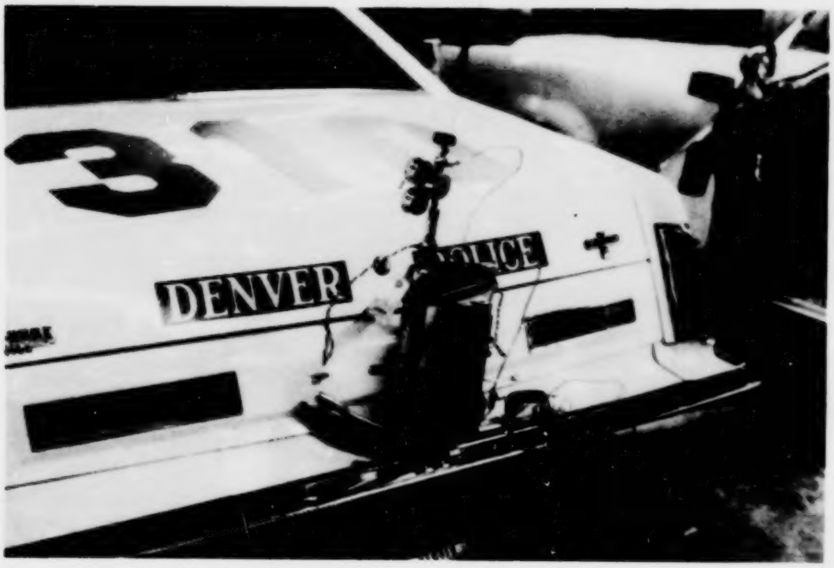


Figure 3-6. Clearing of SF_6 from a Police Car in between Tracer Gas Tests



3
DENVER
POLICE

Figure 3-7. Special Test Equipment - SF_6 Injection System

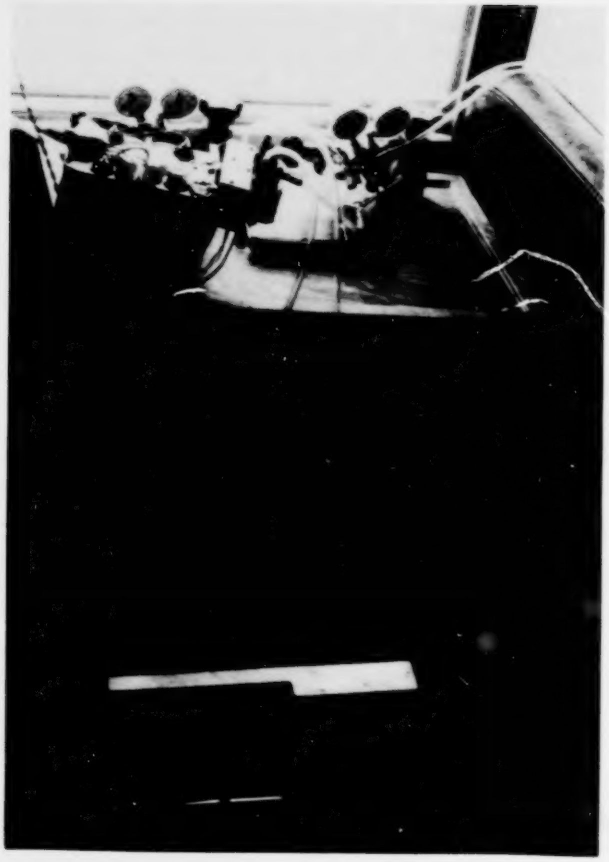


Figure 3-8. Detection and Recording Equipment

rear breathing space sampling locations (trunk mid point for automobiles) and sampling probe for checking intrusion point locations.

For continuous detection of SF_6 concentration in air brought through the sampling system, an SAI real-time continuous SF_6 monitor was utilized. The instrument operates on an electron capture gas chromatograph principle. Ambient background concentration of SF_6 is generally sufficiently low (typically 0.1 to 0.01 parts per trillion) that it can be neglected. The device is real time SF_6 continuous monitor, self contained, portable, and can operate for up to 24 hours. SF_6 is an ideal gaseous tracer material because it is nontoxic, chemically inert, colorless, and can be detected at very low concentrations (10^{-4} ppm).* This instrument utilizes SF_6/O_2 separation by catalytic reactor and electronic capture detection specific to SF_6 to provide a linear coulometric response from 10^{-8} to 10^{-11} parts per million. The particular model used here is portable and relatively insensitive to vibration or position, thereby making it ideal for this type of on-the-road testing. The detection system is shown in Figure 3-8.

A sample recorder trace is shown in Figure 3-9 and annotated in Table 3-4. By following the time-concentration-vehicle location relationships, the approach to equilibrium can be observed as can the principal intrusion pathways. Specifically, despite the release location being the bus tailpipe exhaust, it can be observed that the SF_6 enters through the steering column and gear shift openings rather than at the vehicle rear, and, that within approximately 7 minutes, an equilibrium concentration is reached throughout the vehicle.

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* Collins, 1965

Figure 3-9
Sample SF_6 Test Recording Trace

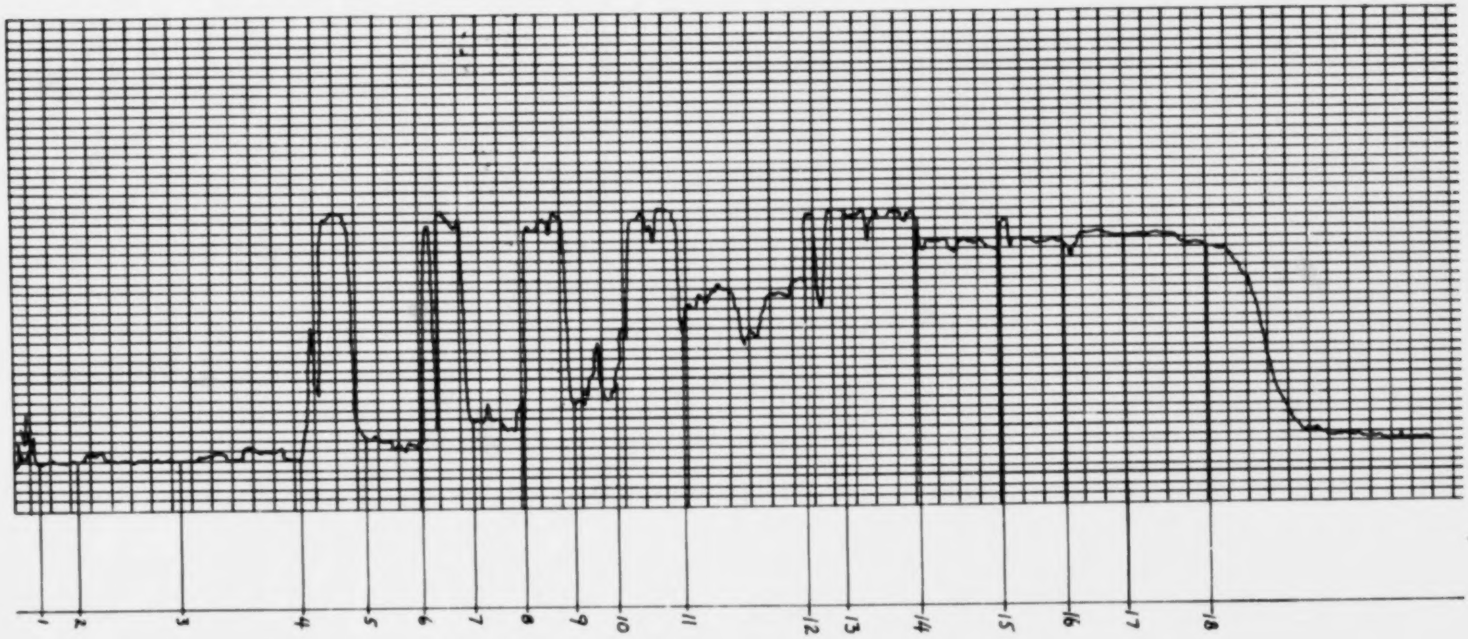


Table 3-4
SF_6 SAMPLE TEST LOG

REFER TO
FIGURE
3-9

Vehicle Type - School Bus
Vehicle Condition - Idling
SF_6 Release Location - Exhaust Outlet
Chart Speed - 2 cm/min
500 mvfs.

From	To	Log-Sampling Location
1	2	Front Bus Baseline
2	3	Rear Bus Baseline
3	-	Start Releasing SF_6
3	4	Rear Bus
4	5	Base Steering Column
5	6	Rear Bus Bottom Emergency Door
6	7	Base Steering Column
7	8	Front Bus Driver Breathing Level
8	9	Driver Gear Shift Plate
9	10	Front Bus Breathing Level
10	11	Driver Steering Column
11	12	Rear Bus Breathing Level
12	13	Base Steering Column
13	14	Bottom of Front Door
14	15	Rear Bus Breathing Level
15	16	Front Bus Breathing Level
16	17	Rear Bus Breathing Level
17		Stop Releasing SF_6
18		Open Windows

SECTION 4

EXPERIMENTAL RESULTS

FLEET SUMMARIES

Fleet Descriptions

The study population consisted of school buses, taxicabs, and police vehicles from selected fleets in the Boston and Denver metropolitan areas. In Denver, four school districts, having a total of nine distinct bus terminals, participated. In Boston, two bus companies were involved. Two Denver area police agencies, having six dispatch points, were tested. Finally, one taxicab company in each city participated.

These arrangements offered the opportunity to survey a large and diverse vehicle population under a variety of use and environmental conditions. Each fleet tended to be composed of one or more blocks of vehicles purchased in quantity. Nearly all vehicles were gasoline fueled, which was considered appropriate since the study dealt with carbon monoxide. The service routes covered by the vehicles varied with respect to traffic density, altitude, proximity to fixed monitoring stations, and other variables which could have influenced results.

Each vehicle was given a preliminary inspection at the start of the testing. Table 4-1 summarizes the gross observable characteristics of each fleet.[+] These preliminary data were compiled and used during test planning and analysis of measurement results. It can be seen in Table 4-1 that taxi cabs have the greatest average mileage and police vehicles the least. The mileage interval between tuneups varies widely among school buses as does the condition of the exhaust systems and intrusion pathways. The figures must be considered somewhat approximate since in all cases they were obtained from individual subjective judgements (condition) and sometimes extrapolated from the most recent maintenance figures (average, total, and post tuneup mileage). Figures 4-1 through 4-5 illustrate views of each primary vehicle type.

[+] The tabulations for categories Exhaust System Deterioration and Intrusion Pathways Observed are taken from the technician completed inspection sheets. Each technician was to record only obvious conditions such as visible soot spots and holes respectively.

Table 4-1

SELECTED FLEET CHARACTERISTICS

FLEET CODE	# VEHICLES	DESCRIPTION	APPROXIMATE AVE. MILEAGE (x 1000 miles)	AVERAGE MILEAGE SINCE TUNEUP	EXHAUST SYSTEM DETERIORATION (%)	INTRUSION PATHWAYS OBSERVED(%)
School Buses						
B-1-A	102	1969-1977 wide range of mfg.	75	6,000	10	N/A
B-2-A	30	Principally 1973-1975 Int'l	65	8,000	0	33
B-2-B	27	Principally 1975-1976 Ford	50	4,000	30	0
B-3-A	101	Wide Variety 1970-1978	50	3,000	5	5
B-3-B	150	Principally 1970-1976 Int'l	65	3,000	5	N/D
B-4-A	54	Varied 1966-1978	80	8,000	5	5
B-4-B	43	Varied 1966-1978	80	8,000	N/D	20
B-4-C	75	Varied 1966-1978	80	8,000	N/D	20
B-4-D	47	Varied 1966-1978	80	8,000	N/D	30
B-5-A	84	All are International 1977	20	< 500	31	24
B-6-A	80	All GMC 1970-1975	50	N/A	59	58
Police Cars						
P-1-A	27	78 Ford Ltd 78 Chevy Nova 77-78 Pont.	30	10,000	5	3
P-1-B	31					
P-1-C	26					
P-1-D	29					
P-2-A	14	76-78 Plymouth	45	8,000	14	N/D
P-2-B						
Taxicabs						
T-1-A	243	74-79 Checker	200	6,000	6	70*
T-2-A	63					

---

* Common situation was opening between rear seat and trunk

Figure 4-1. Sustained-Use Vehicles Being Readied For Special Testing Phase

Figure 4-2. Exhaust System Leak Examination for a Sustained-Use Vehicle

Figure 4-3. Comparative Inspection of Sustained-Use Vehicles

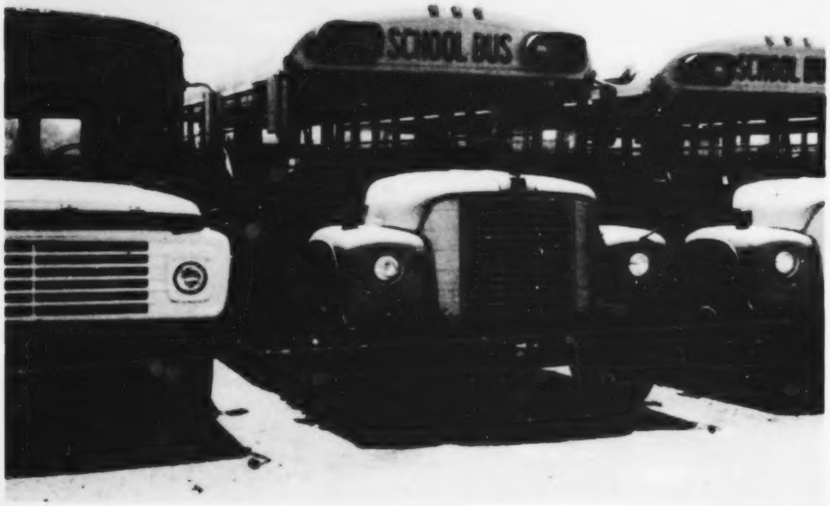

SCHOOL BUS
SCHOOL BU

Figure 4-4. Typical Depot Parking Arrangement of Sustained-Use Vehicles

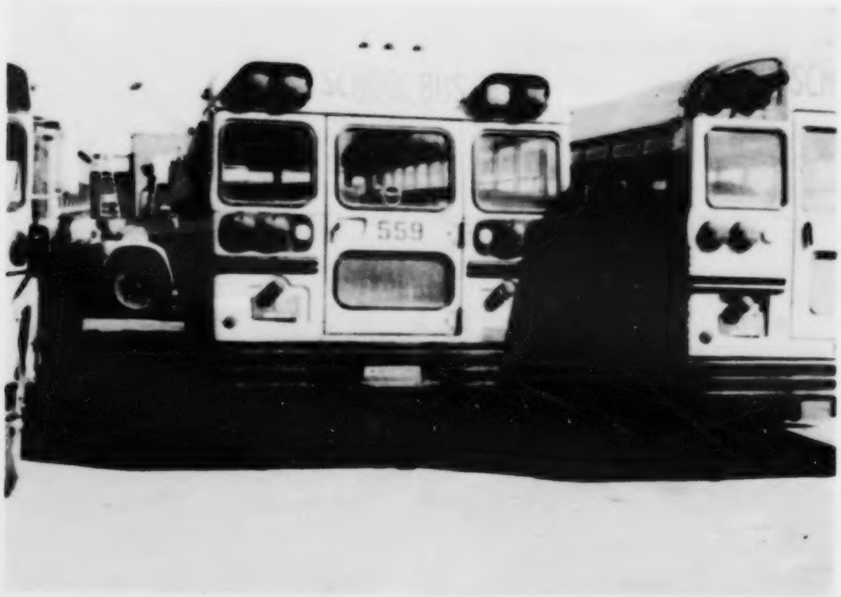


Figure 4-5. Emergency Door Configuration

Results of Initial Screening

Carbon monoxide was measured in 1,164 vehicles by at least one of three devices: glass tube dosimeters, personal samplers, and continuous analyzers. Table 4-2 reports the number of vehicles sampled by each technique.

Glass Tube Dosimeter Measurements--

One or two MSA glass stain tube dosimeters were installed in 749 buses, 295 taxis, and 70 police cars. Sampling time distributions varied considerably among vehicle types. As seen in Figure 4-6, the bus exposure time distribution was bimodal, with peaks at 6 to 6.5 hours and 9 to 9.5 hours; the former represent runs in which the buses returned for the day at noon, while the latter represent the normal pattern of two round trips per day. Almost 80 percent of the runs were between 8.5 and 10 hours. The mean and standard deviation were 9.2 and 1.0 hours, respectively.

Taxi runs ranged from less than 4 hours to over 15.5 hours and were more widely distributed(mean = 9.8 hours, s.d. = 2.2 hours)than the bus runs. It should be noted that taxis were in general on the road throughout their daily runs, while buses spent three to five hours per day at their home terminals. Thus, the actual on-the-road CO exposure time was significantly higher for taxis. All but 6 of the 120 police vehicle measurements were made on 8-hour on-the-road runs.

Stain tubes were used to make 1,139 interior-front and 455 interior-rear measurements of CO. As is discussed in Appendix B, tube readings for 18 of the buses and 7 of the police vehicles were considered unreliable and were omitted from the results. On the other hand, 113 measurements were made on 63 police cars in the P-1 fleet.

Table 4-3 summarizes the results of the glass stain tube dosimeter measurements. Because of the uncertainties inherent in this measurement approach (see Appendix B), concentrations are presented to the nearest 5 ppm. Data have not been corrected for background CO concentrations as measured by fixed site monitoring stations, since the latter measurements were in almost all cases smaller than the error inherent in this phase of the study. For example, during tests on Fleet B-5, for which the 95-percent confidence interval for mean CO concentration was 5-10 ppm, the corresponding interval for the nearest fixed site station was 1.1-3.0 ppm.

It is clear from Table 4-3 that occupants of a large fraction of the vehicles tested were apparently exposed to CO concentrations exceeding the 9-ppm 8-hour National Ambient Air Quality Standard or the 35-ppm 1-hour standard. Drivers of taxis and police cars were most likely to be subjected to the excessive 8-hour exposures, since bus drivers are in their vehicles for less than 8 hours daily. It is not possible to tell from these data whether any excessive one-hour exposures were received. However, certain vehicles received relatively high cumulative exposures. One bus and two police cars had average CO levels of 80 to 85 ppm over a workday. The mean value for highest-in-fleet CO concentrations was 35 and 30 ppm for buses (front and rear, respectively), 35 ppm for taxis and 55 and 30 ppm for police

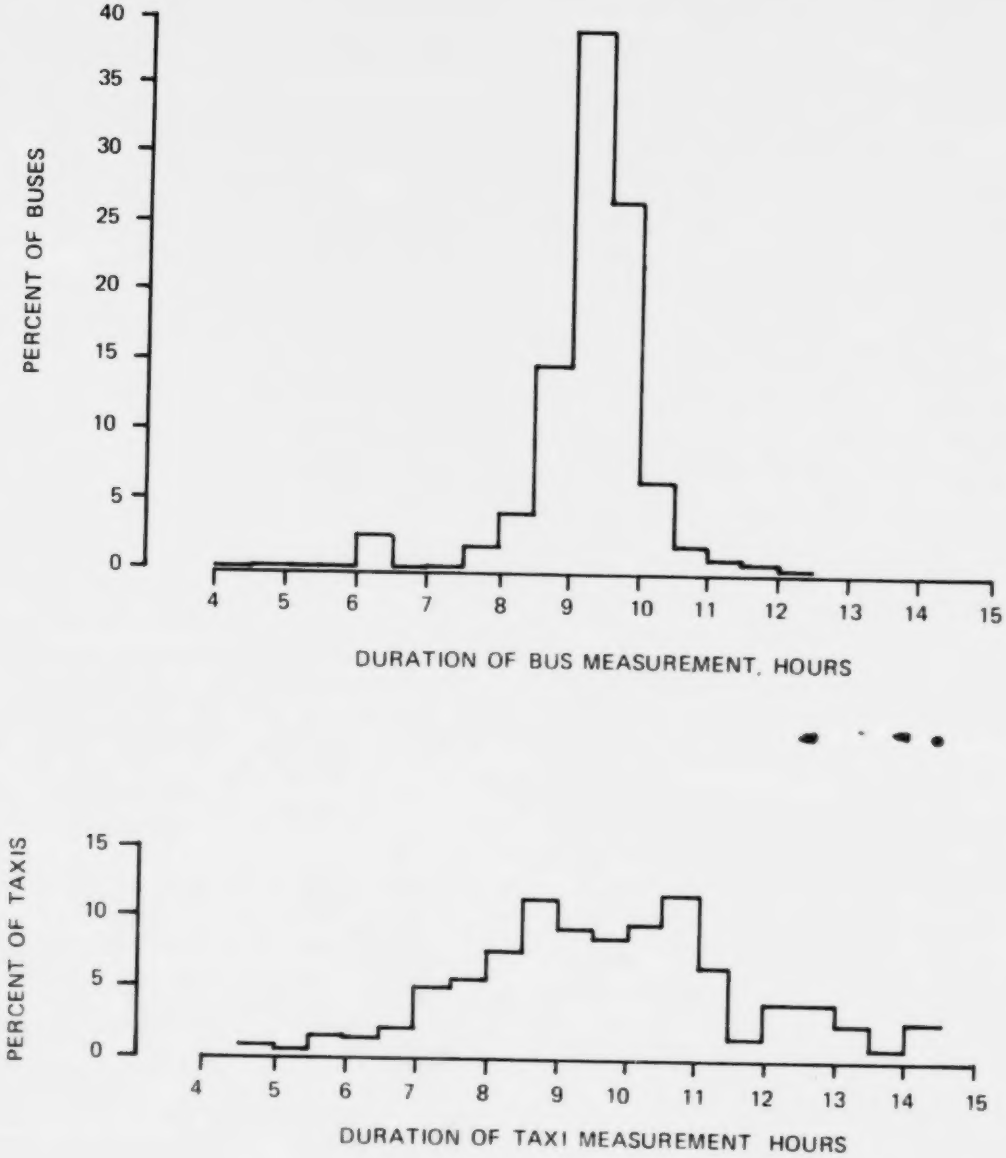


Figure 4-6. Duration of Bus and Taxi Rides for Glass Stain Tube Dosimeter Measurement.

Table 4-2

NUMBER OF VEHICLES MEASURED

PARTICIPANT CODE	GLASS TUBE DOSIMETERS		PERSONAL SAMPLERS		CONTINUOUS ANALYZERS	
	No.	Pct.	No.	Pct.	No.	Pct.
Buses						
B-1-A	102	100	0	0	0	0
B-2-A	30	100	13	43	5	17
B-2-B	23	85	15	56	0	0
B-3-A	101	100	7	7	7	7
B-3-B	150	100	12	8	0	0
B-4-A	42	78	0	0	5	9
B-4-B	43	100	0	0	7	16
B-4-C	54	72	0	0	2	3
B-4-D	47	100	0	0	4	9
B-5-A	73	87	14	17	4	5
B-6-A	73	91	14	18	3	4
Total Buses	749	94	75	9	37	5
Taxis						
T-1-A	232	95	38	16	7	3
T-2-A	63	100	0	0	6	10
Total Taxis	295	96	38	12	13	4
Police Cars						
P-1-A	27	100	5	19	5	19
P-1-B	31	100	4	13	0	0
P-1-C	26	100	5	19	1	4
P-1-D	29	100	5	17	0	0
P-2-A	7	50	0	0	9	66
P-2-B			0	0		
Total Police Cars	120	94	19	15	15	12

[a] Pct= Percent of Fleet

Table 4-3

RESULTS OF GLASS TUBE DOSIMETER MEASUREMENTS
(All concentrations in parts per million)

Fleet/Terminal Code	Front			Rear		
	No. of Vehicle Measurements	95-Pct Confidence Interval for Mean CO Concentration	Max. CO	No. of Vehicle Measurements	95-pct. Confidence Interval for Mean CO Concentration	Max. CO
Buses						
B-1-A	102	0- 5	20	53	5-10	30
B-2-A	30	10-20	55	5	0-25	30
B-2-B	23	10-20	55	23	10-20	50
B-3-A	101	10-15	40	53	15-25	80
B-3-B	150	5-10	25	62	5-10	20
B-4-A	42	5-10	25	3	0-15	10
B-4-B	43	10-25	50	4	0-15	10
B-4-C	54	5-10	20	7	0-30	50
B-4-D	30	5-20	70	3	0-15	10
B-5-A	83	5-10	25	84	5-10	30
B-6-A	73	5-10	25	71	5-10	25
Taxis						
T-1-A	232	20-25	55	NM[a]	NM	ND
T-2-A	63	5-15	20	62	5-15	15
Police Cars						
P-1-A	27[b]	10-25	85	8[b]	5-20	30
P-1-B	31[b]	5-15	85	7[b]	0-15	30
P-1-C	26[b]	15-20	30	6[b]	10-20	20
P-1-D	29[b]	10-15	20	7[b]	0-25	35
P-2-A	UD[c]	UD	UD	NM	NM	NM
P-2-B	UD	UD	UD	NM	NM	NM

[a] NM = Not measured

[b] Several vehicles tested more than once

[c] UD = Unreliable data

cars (front and rear).

Several statistical tests were performed to see whether there were significant relationships (correlations or differences in means) between:

- Front and rear interior concentrations within a particular fleet;
- Concentrations in vehicles from different terminals in a particular fleet; or,
- Concentrations on different dates.

In several cases, statistically significant ($p < 0.05$) relationships were found. For example, both front and rear CO concentrations were higher in buses from terminal B-3-A than in those from terminal B-3-B (10-15 vs 5-10 ppm). Similarly, buses from terminal B-4-B had higher CO levels than buses in terminals B-4-A, B-4-C, and B-4-D. Correlations between front and rear interior CO concentrations were always low (< 0.5).

Given the great uncertainty in the stain tube dosimeter data, statistical inferences such as these must be qualified. Based upon stain tube data alone, conclusions cannot be made regarding possible intrusion pathways or the extent of carbon monoxide intrusion. However, the stain tube data and the interpretations thereof were useful in selecting vehicles and terminal locations for the more accurate, precise, and reliable personal sampler, continuous monitoring, and tracer gas testing later in the project.

Personal Sampler Measurements--

Cumulative work-shift exposure measurements were made with ESI® 9000 Carbon Monoxide Dosimeters worn by 132 drivers. These measurements represent about 11 percent of the total vehicles surveyed. Three problems were responsible for the inability to make the greater number of personal sampler measurements contemplated in the original study plan. First, at any given time, as many as half the dosimeters and/or pumps were out of order. The major causes of unavailability were failure of pumps to recharge overnight, broken fittings, and failure to calibrate properly, even after proper humidification. Second, it was the policy throughout only to use volunteers for the personal sampler measurements, and the full complement of drivers in certain fleets were unwilling to participate. Finally, 24 personal sampler readings were discarded because, despite satisfactory checkout, it was suspected afterwards that something had been awry with the equipment; the most common problems were poor repeatability of readings on the readout device and unreasonably high or low values for cumulative exposure. An example of a suspect measurement is an average exposure of 177 ppm over a 9-hour period in taxi T-1-A-202. While the CO concentration could conceivably reach that level in a passenger vehicle, the driver, who would have exhibited symptoms of acute CO exposure in this case, did not complain of any problems. Furthermore, such high levels would have been due to vehicle self-contamination and would have resulted in correspondingly high glass stain tube dosimeter readings. In no case did this occur. Continuing the above example, the corresponding stain tube

Table 4-4

RESULTS OF PERSONAL SAMPLER MEASUREMENTS
(All concentrations in ppm)

Fleet/ Terminal Code	No. of Valid Vehicle Measurements	95-percent Confidence Interval for Mean CO Concentration		Maximum CO Within Fleet	
		Total Exposure	Exposure Minus Fixed Site Ambient	Total Exposure	Exposure Minus Fixed Site Ambient
Buses					
B-1-A	NM[a]	NM	NM	NM	NM
B-2-A	13	8 - 36	7 - 34	84	83
B-2-B	15	4 - 25	3 - 24	61	60
B-3-A	7	4 - 29	2 - 27	43	42
B-3-B	12	12 - 23	9 - 21	35	35
B-4-A	NM	NM	NM	NM	NM
B-4-B	NM	NM	NM	NM	NM
B-4-C	NM	NM	NM	NM	NM
B-4-D	NM	NM	NM	NM	NM
B-5-A	14	4 - 7	ND[b]	11	ND
B-6-A	14	13 - 34	9 - 29	68	64
Taxis					
T-1-A	38	10 - 17	8 - 15	48	47
T-2-A	NM	NM	NM	NM	NM
Police Cars					
P-1-A	5	0 - 37	0 - 34	39	36
P-1-B	4	2 - 21	0 - 20	18	18
P-1-C	5	0 - 46	0 - 44	59	58
P-1-D	5	2 - 24	0 - 19	21	17
P-2-A	NM	NM	NM	NM	NM
P-2-B	NM	NM	NM	NM	NM

---

[a] Not measured

[b] No fixed site data available

reading for vehicle T-1-A-202 was 25 ppm, within the normal range for that fleet.

Table 4-4 summarizes the results of the personal sampler testing. Measured CO concentrations are expressed to the nearest ppm. The table presents both the total exposures and the differences between the total exposures and the average background CO concentration as measured by the nearest fixed site monitoring station(s) on the same day and during the same time interval as the personal sampler measurements.

Total exposures exceeded background concentrations by an average of 13.9 ± 1.4 ppm (95 percent confidence interval). How much of this difference was due to vehicle self-contamination and how much was due to the inherent lack of representativeness of the fixed site monitoring station readings cannot be discerned from these data. Chi-square analysis of taxicab data showed that CO levels were not significantly higher when driver and/or passengers smoked.

It is informative to compare the personal sampler results with the EPA eight-hour ambient air quality standard for carbon monoxide (9 ppm). Figure 4-7 shows the distribution of personal sampler readings for rides of at least eight hours. In 58 percent of the cases, the 8-hour standard was exceeded. The Occupational Safety and Health Administration (OSHA) standard of 50 ppm average over an 8-hour period was exceeded in 5 percent of the cases.

In general, the 95th percentile CO concentrations measured by the personal samplers were higher than those measured by the glass stain tube dosimeters. Although the greater width of the confidence interval could be suspected of being a statistical artifact (since far fewer personal sampler measurements were made), the variances in personal sampler results were for all fleets twice those of the tube results. Correlation coefficients for stain tube and personal sampler readings on the same vehicles were calculated for fleets B-2-B, T-1-A, P-1-A, P-1-B, and P-1-C to be 0.14, 0.29, 0.96, 0.51 and 0.47, respectively. Only in the case of P-1-A was there a high correlation. As noted in the previous section, the great uncertainty in the stain tube data limits the value of these statistical analyses.

CONTINUOUS MONITORING RESULTS

Interscan® Model 1146 carbon monoxide continuous analyzers were used to measure instantaneous carbon monoxide concentrations in 37 buses, 13 taxis, and 10 police vehicles. Strip chart recordings made on Soltec® Model VP-67235 dual-channel recorders permitted later identification of peaks and calculation of mean CO concentrations over any time interval desired. While the continuous CO monitoring results were, by opinion, the most accurate of those obtained in this program, not enough measurements were made to permit characterization of any particular fleet, city, or vehicle type. On the other hand, these results were useful for:

- Pinpointing and quantifying peak CO concentrations and associating them with potential causal factors;

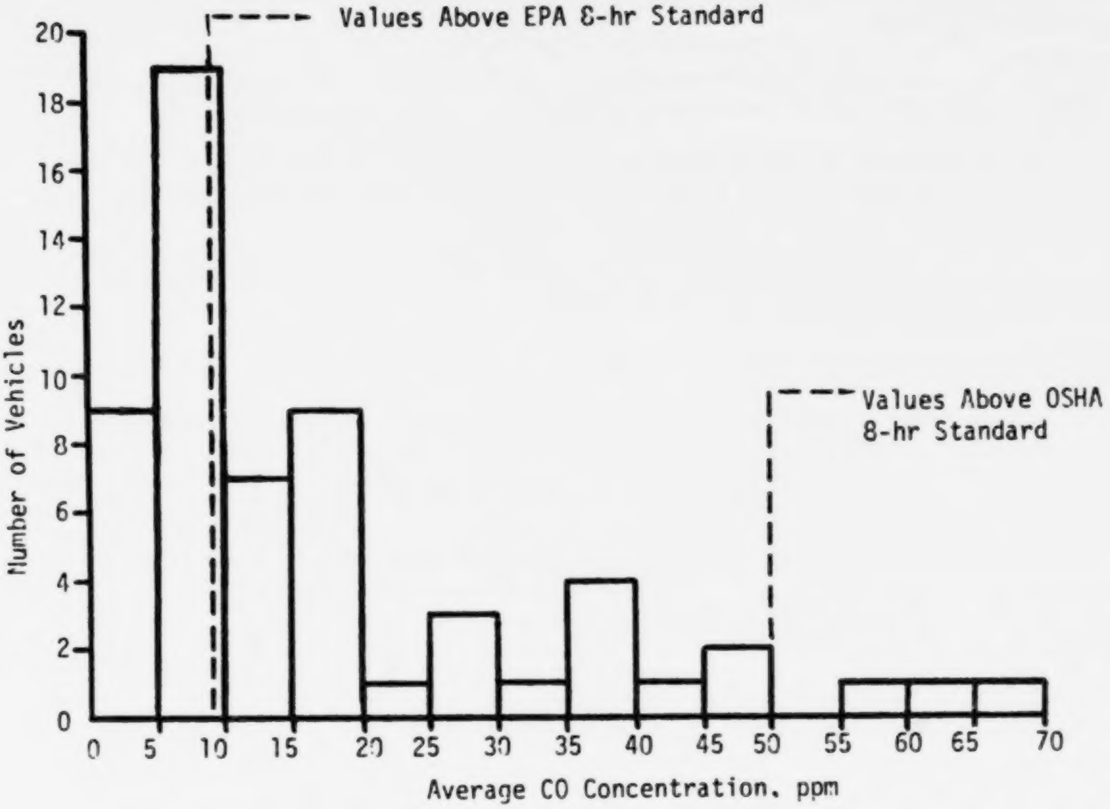


Figure 4-7. Distribution of Personal Sampler Readings for Runs of at Least Eight Hours

- Identifying operating conditions under which interior CO concentrations exceeded exterior concentrations, whether due to vehicle self-contamination or other factors;
- Identifying conditions which lead to interior CO concentrations approaching or exceeding ambient air quality standards; and,
- Comparing actual passenger exposure levels to the ambient CO concentrations measured by fixed site monitoring stations.

Figure 4-8 shows a portion of a typical continuous monitoring record. The letters on the chart are keys to the technician's comments, the corresponding sample of which are shown in Figure 4-9.

Time-Weighted Average Concentrations

Strip chart recordings of 12 continuous monitor runs were measured with a planimeter to determine the cumulative CO exposure over half-hour intervals. Time-weighted average CO concentrations were then computed by dividing cumulative exposures by the appropriate duration. Table 4-5 lists the calculated concentrations. Although one cannot draw conclusions about average within-fleet concentrations, the results presented in this table are neither unusually higher nor lower than those for other runs. Strip-chart records can be misleading to the untrained eye, which are drawn to the peaks. The total time represented by peak concentrations is relatively short. Figure 4-10 shows the cumulative frequency distribution of the interior exposures measured in Vehicle B-2-A-1148. Although interior CO levels of 30 to 50 ppm were measured, concentrations were below 7 ppm for over half of the time of the run.

Peak Concentrations

Table 4-6 lists values of peak interior and exterior CO concentrations in 22 of the 60 vehicles measured with continuous monitors. While data are insufficient to characterize the fleets to which these vehicles belong, we may state qualitatively that the ranges of values reported in the table are typical of all the continuous monitor measurements. In a large number of cases, the instantaneous exterior CO concentration exceeds the limit of the Interscan scale (50 or 100 ppm). Interior peaks were generally below these limits but did exceed them on several occasions. As noted above, the duration of peak CO concentration is typically relatively short. For example, while the interior CO concentration in vehicle NO. B-2-A-1148 exceeded 50 ppm on 3 occasions, it was above 45 ppm for only 1.6 minutes of a 159-minute ride.

Strip chart records and technician comments were scrutinized to identify conditions or events which led to the peak concentrations. Relatively high CO concentrations were associated with the following:

Exterior CO

- Bus stops to pick up or drop off students

Figure 4-8

Typical Monitoring Record

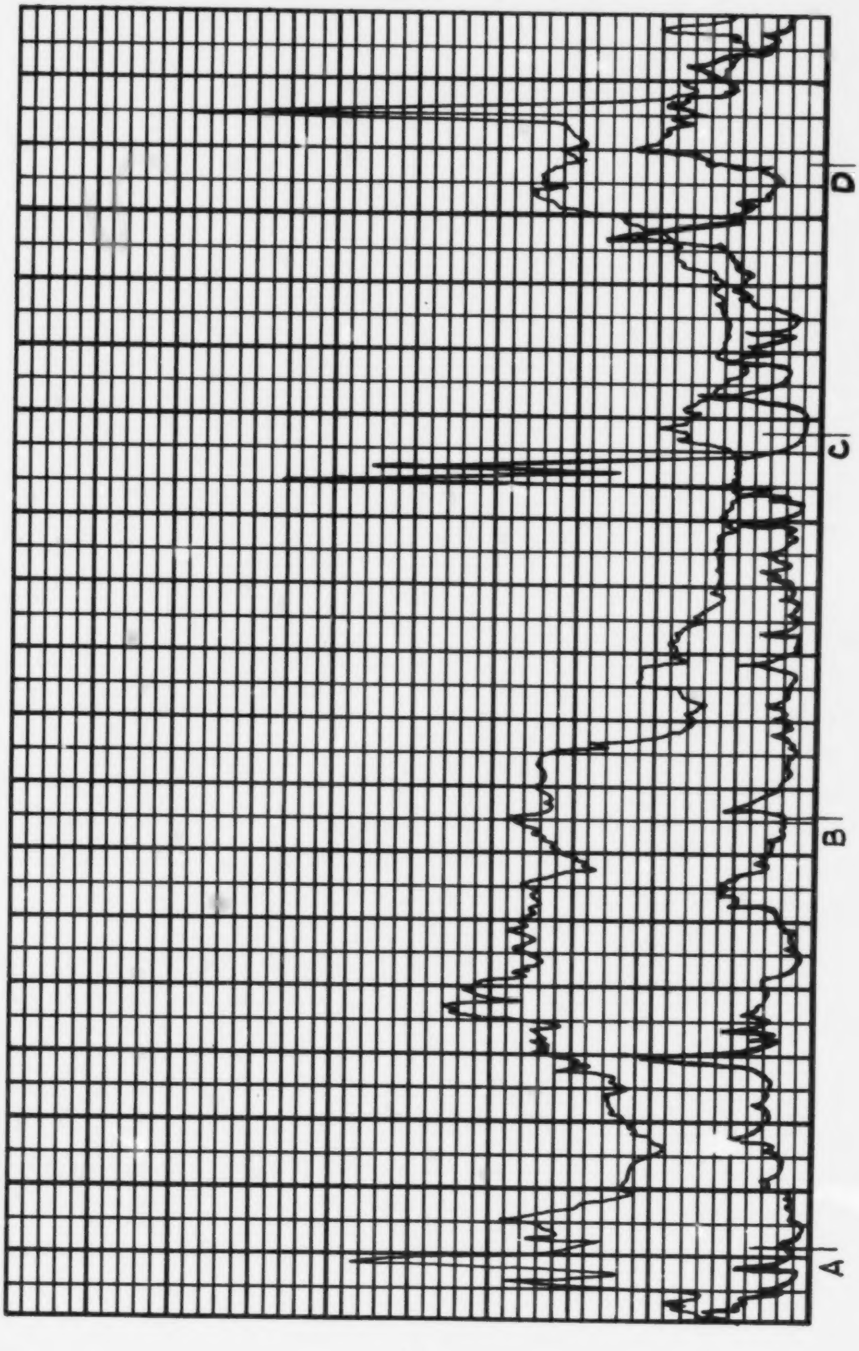


Figure 4-9

Technical Data Sheet Comments

CODE	TYPE	DESCRIPTION
	1:35	Engine Started (in lot) Set up in front seat
		Behind driver (Driver's side window ½ open)
		—(All windows closed to start)
A	1:40	Left Terminal (headed south)
B	1:55	Parked at Columbine High (S.E. Jeffco)
		Engine on - Front door open
C	2:05	Left Columbine with 3 Kids
D	2:15	Packed at Ken Caryl Jr. High, Engine off, Door open
E	2:18	Moved back to center (left) of bus
F	2:25	Engine on
G	2:26	Left Ken Caryl with 16
H	2:40	All Kids off; headed East
I	2:50	Parked at Columbine High (engine off)
J	2:51	Moved equipment to back Right of Bus
K	2:58	Left Columbine with 18 Kids
L	3:35	Everyone off, headed north (to B.C.)
M	3:45	In terminal, (waiting for gas)
N	3:47	Engine off (filled w/gas) front door open
O	4:00	Engine on - moved to parking space
P	4:00	Engine off

Table 4-5

ANALYSIS OF SELECTED CONTINUOUS MONITORING DATA: (1) TIME-WEIGHTED AVERAGE CO CONCENTRATIONS

Vehicle No.	Time Weighted Average CO Concentration (ppm)		
	Interior	Exterior	Fixed Station
B-2-A-1084	9.2	9.3	1.5
B-2-A-1095	19.1	4.9	NA[a]
B-2-A-1100	5.1	10.7	NA
B-2-A-1148	7.3	8.0	1.5
B-4-A-200	2.1	5.7	1.5
B-4-A-322[b]	8.0	11.4	3.0
B-4-A-322[c]	8.4	13.0	4.4
B-4-A-397	1.4	4.7	1.4
B-4-B-200	7.8	6.4	0.0
B-4-B-357	4.0	9.0	0.8
T-1-A-588	13.5	17.6	6.1
T-2-A-67	21.2	23.3	NA

[a] Data unavailable for sampling date.

[b,c] Runs on separate days

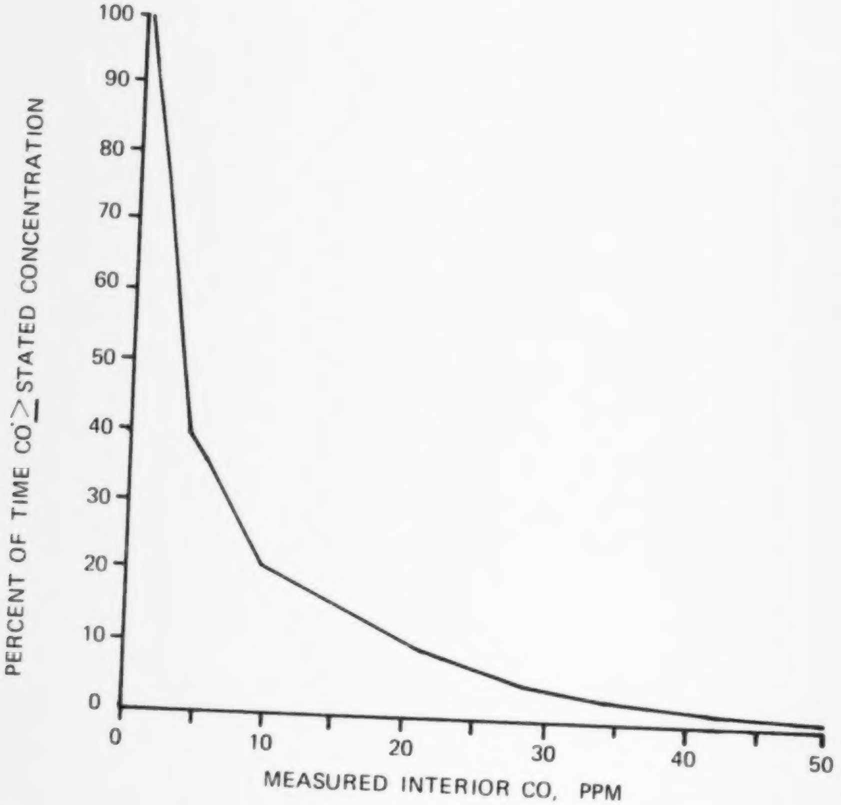


Figure 4-10. Time Distribution of CO Concentrations Inside Vehicle B-2-A-1148.

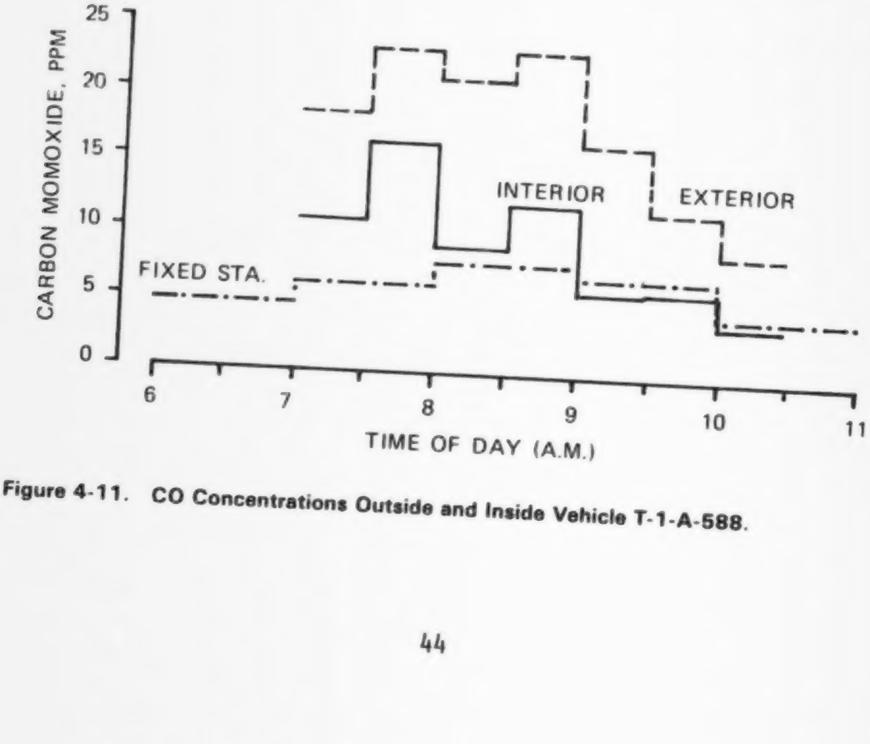


Figure 4-11. CO Concentrations Outside and Inside Vehicle T-1-A-588.

Table 4-6

ANALYSIS OF SELECTED CONTINUOUS MONITORING DATA: (2) PEAK INTERIOR AND EXTERIOR CONCENTRATIONS AND RELATIONS BETWEEN INTERIOR AND EXTERIOR LEVELS

Vehicle No.	Peak CO Concentration (ppm) Interior	Exterior	Pct. of Time Interior CO > Exterior CO
B-2-A-1084	>50	>50	9
B-2-A-1095	>50	>50	100
B-2-A-1100	31	>50	3
B-2-A-1148	>50	>50	10
B-3-A-28	26	>50	52
B-3-A-76	23	41	75
B-3-A-457	>50	>50	21
B-3-A-480	>50	>50	31
B-3-A-527	34	>50	13
B-3-A-567	42	>50	54
B-4-A-200	36	>50	1
B-4-A-322[a]	45	>50	17
B-4-A-322[b]	22	>50	17
B-4-A-368	13	39	0
B-4-A-388	17	38	0
B-4-A-397	14	29	0
B-4-B-200	34	>50	0
B-4-B-357	30	>50	11
B-4-C-14	47	>50	NS[d]
B-4-C-363	22	>50	NS
B-4-D-283	>50	NM[c]	NS
T-1-A-588	35	>100	0
T-2-A-67	>100	>100	50

[a,b] Runs on separate days

[c] No measurement made

[d] Interior and exterior measurements not made simultaneously

- Long wait at a stop sign or red light
- Bus idling at terminal
- Engine start-up
- Other buses passing by or idling next to measured vehicle
- Heavy traffic
- Travel through downtown area

Interior CO

- Bus stops to pick up or drop off students
- Long wait at a stop sign or red light
- Bus idling with window open
- Other buses passing by or idling next to measured vehicle
- Bus has strong smell of fumes inside

Relation Between Interior and Exterior Exposures

The "normal" relation between interior and exterior CO concentrations is illustrated in Figure 4-11, which summarizes data from a taxicab run. Interior concentrations rise and fall with exterior concentrations, yet are almost always lower. The reason interior levels are considerably lower may be that the relatively small difference between interior and exterior levels provides too small a driving force for diffusion of CO into the vehicle. Furthermore, there is insufficient time for the two concentrations to equilibriate, since the external source is constantly changing as long as the vehicle keeps moving.

Figure 4-12 shows an opposite case; interior CO levels exceed exterior levels throughout the run. (In this and the following figures, cross hatched areas correspond to time period during which interior CO concentrations are higher than exterior concentrations. In this particular case(Vehicle B-2-A-1095), the technician reported:

> "You can noticeably smell fumes most of the time. Windows were mostly closed, some not tight. Driver says there is hole around accelerator."

Evidence indicates a strong possibility of vehicle self-contamination. Another situation is exemplified in taxi T-2-A-67, CO concentrations in and outside, which are displayed in Figure 4-13. Here interior levels exceeded exterior levels only part of the time.

The fourth column of Table 4-6 shows the percentage of the time (on each

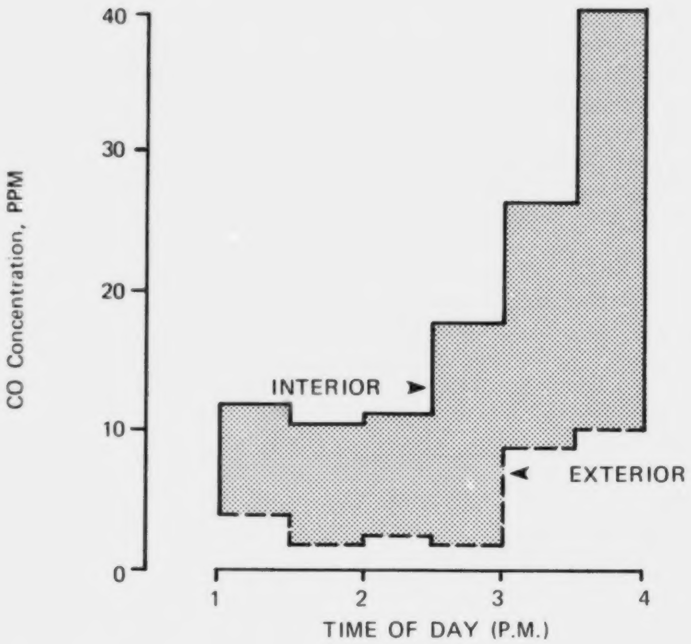


Figure 4-12. CO Concentrations Outside and Inside Vehicle B-2-A-1095.

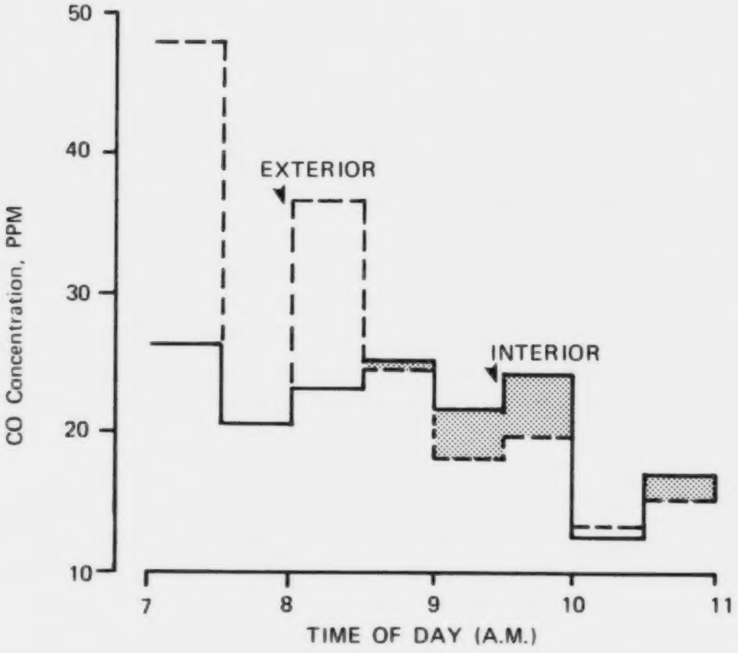


Figure 4-13. CO Concentrations Outside and Inside Vehicle T-2-A-67.

run) that measured interior CO levels exceeded exterior levels. There is no obvious pattern; percentages varied from 0 to 100 percent. Conclusions about the likelihood of relatively higher interior CO concentrations cannot be drawn from these data largely because the vehicles tested were chosen for continuous monitoring precisely because they had exhibited high interior CO concentrations in the glass stain tube dosimeter and personal sampler measurements described above. However, it is possible to gain some insight into mechanisms of intrusion by reviewing the technician's comments.

In the case of Vehicle B-2-A-1148, higher interior CO concentrations were observed during a 15-minute period when the bus was idling with the front door open in a parking lot, while children were boarding. The preliminary vehicle inspection showed no gross physical defects. Similarly, Vehicle B-3-A-28 was reported to be in good condition. However, the bus' windows were closed during the entire continuous monitoring measurement run, for which interior CO exceeded exterior CO for 52 percent of the time.

Vehicle B-3-A-76 was, according to the preliminary inspection, in good condition. Continuous monitoring measurements were made on a cold day with intermittent snow. The bus' heater was on for the entire run, during which interior CO concentrations exceeded exterior concentrations 75 percent of the time.

During testing of vehicle B-3-A-480, which had relatively high interior CO levels 31 percent of the time, windows were opened and closed several times. The higher interior CO concentrations were observed when one-quarter or half the windows were closed; when all windows were closed, exterior CO levels were higher. Again, the bus was judged on preliminary inspection to be in good condition.

Vehicle B-3-A-567 was found on preliminary inspection to have small openings on the floorboard near the foot pedals and a poor seal between the gear shift boot and the floor. CO levels were higher inside for 54 percent of the time. The relatively high interior levels were detected both when windows were half open and all closed.

SPECIAL TESTING: OVERVIEW OF DATA COLLECTION AND INTERPRETATION

A summary of test data and results for the special testing is presented in this section. The results are organized and presented in the same order and corresponding to the three basic procedures of the test program as described in Section 3.

CO Source Location Identification Results

A summary of exhaust system leaks (CO source locations) for all tested vehicles is presented in Table 4-7. The vehicle types are listed separately since the exhaust system configurations are significantly different for school buses than for automotive vehicles. The tabulated leak locations are ordered from left to right in the same order that the exhaust flows through the system. Particularly severe leaks are identified by the star superscript. As can be seen, leaks were found at every connection of the exhaust system and

Table 4-7

Summary of Vehicle Exhaust System Leak Locations Determined by CO Monitor Test Procedures

VEHICLE TYPE	I.D.	Engine Exhaust Manifold	Manifold to Head Pipe	Head Pipe to Exhaust Pipe	Along Exhaust Pipe	Exhaust Pipe to Muffler	Muffler	Muffler to Tail Pipe	Along Tail Pipe	
School Bus	B-5-A-314			X		X				
	B-5-A-405	X		X						
	B-5-A-211		X	X	X	X		X*	X*	
	B-5-A-115	X	X		X*	X	X	X*		
	B-5-A-320	X				X*		X*		
	B-5-A-123		X			X				
	B-5-A-315		X*			X				
	B-5-A-327	X		X*		X*		X*		
	B-4-B-344	X*	X*					X		
	B-4-B-342		X					X		
	B-3-B-355	X*	X*					X		
	B-3-B-183		X	X						
	B-3-A-83		X	X						
	B-3-A-93		X	X		X		X		
	B-3-A-567	X	X	X		X		X		

VEHICLE TYPE	I.D.	Engine Exhaust Manifold	Manifold to Head Pipe	Head Pipe to Catalytic Converter	Catalytic Converter to Exhaust Pipe	Exhaust Pipe to Muffler	Muffler	Muffler to Tail Pipe	
Taxi Cab and Police Car	T-2-A-616	X	X			X	X	X	
	T-2-A-67	X		X			X	X	
	T-2-A-79	X	X				X*	X*	
	T-2-A-59	X	X	X	X*	X*	X	X*	
	T-1-A-685	X		X	X	X	X	X*	
	T-1-A-216		X	X	X	X	X		
	P-1-A-358		X	X*			X		
	P-1-A-310	X			X	X	X		

*Severe Leak

occasionally in the components (muffler, tail pipe) of the system itself.

The method of leak detection and verification utilizing a CO monitor and a flexible sampling probe proved to be very effective. The thin, flexible sampling probe enabled the identification of exact leak source, small or large, at any location around the exhaust system joints. For example, leaks were often found at the upper part of the exhaust system joints, locations that are otherwise hidden from direct view.

In general, leaks were located in the joints of the system such as pipe to pipe, or pipe to component (muffler, catalytic converter) connections, and only rarely in the components themselves. This indicates that even in a relatively new vehicle with very little corrosion or wear of the muffler and/or exhaust pipes, significant leaks do occur due to poor sealing at the numerous exhaust system connections. As can be seen in the table, almost every vehicle leaked in the area adjacent to the engine compartment, either at the engine exhaust manifold and/or at the joint of the manifold and the head pipe. In and out connections around the catalytic converter in taxi cabs and police cars (none of the buses tested had catalytic converters) and at the muffler in all types of vehicles showed above 30 leaks for the 24 tested vehicles. The average number of leaks for school buses was approximately 3; for taxi cabs and police cars, there were more than 4-5 leaks per vehicle. Figure 4-14 shows examples of exhaust system leak locations that are not visible by inspection alone but can be readily identified utilizing the CO monitor testing method.

CO Intrusion Pathway Inspection Results

Potential CO intrusion pathways were identified by the inspection procedures including inspections underneath the vehicle, in the engine compartment, in the vehicle interior, in the trunk, and other exterior surfaces and panels making up the vehicle interior envelope. The principal results of those inspection procedures are presented in Table 4-8. Again, school buses are presented separate from automobile type vehicles due to their characteristically different configurations. Principal vehicle intrusion pathways are tabulated from left to right starting at the front of the vehicle and moving towards the rear.

For school buses (the upper part of Table 4-8), most of the potential CO intrusion pathways were identified in the driver area. Relatively few intrusion pathways were found directly in the vehicle fire wall; however, often the engine compartment cover was incompletely sealed and there were often leaks around cables and hoses coming into the driver compartment. There were a fair number of potential intrusion pathways identified in the driver floor area such as at the base of the steering column, gear shift and emergency brake. The rubber protective boots around the gear shift and emergency brake were often found damaged and/or deteriorated. There were very few potential intrusion pathways found along the mid section of the bus, such as an occasional missing screw or defective rear wheel gasket. It is important to note that nearly 90% of the inspected school buses had a defective seal around the emergency door due to age, wear, and/or damage. Sometimes this was due to the seal itself and other times due to the fact that the door mechanism

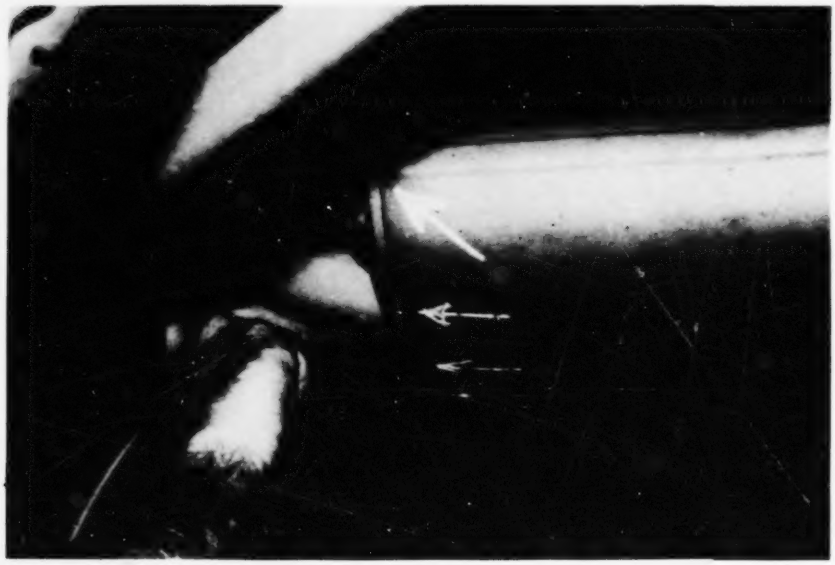


Figure 4-14. An Identified Leak in the Muffler Exterior Utilizing CO Monitor

Table 4-8

Summary of Potential CO Vehicle Intrusion Pathways Identified by Inspection Procedures

VEHICLE TYPE	INTRUSION POINTS I.D.	Fire Wall Seal	Hole/s in Fire Wall	Electrical Lid/s-Engine Compartment	Mechanical Cable/s-Engine Compartment	Heater/Windshield Water Hose	Steering Column Boot/Base	Gear Shift Boot/Base	Emergency Brake Housing	Engine Cover Gasket	Loose/Missing Floor Screws in Driver Area	Front Door Seal	Loose/Missing Screws Under the Seats	Rear Wheel Well Gasket	Window (doesn't shut)	Emergency Door Seal	
School Bus	B-5-A-314			X		X		X								X	
	B-5-A-405				X	X	X									X	
	B-5-A-211			X		X			X							X	
	B-5-A-115			X		X										X	
	B-5-A-320				X	X							X			X	
	B-5-A-123			X		X		X	X							X	
	B-5-A-320					X		X								X	
	B-5-A-327			X	X	X			X*							X	
	B-4-B-344				X	X	X									X	
	B-4-B-342				X		X									X	
	B-4-B-355			X	X		X								X	X	
	B-4-B-183	X	X		X	X	X	X	X							X	
	B-3-A-83					X	X			X	X	X	X				
	B-3-A-93				X			X					X	X		X	

VEHICLE TYPE	INTRUSION POINTS I.D.	Fire Wall	Electrical Lids-Engine Compartment	Vent Inlet Seal	Heater/Windshield Water Hose	Front Windshield Seal	Foot Pedals	Steering Column	Unused Mounting Holes for Back Seat	Door/s Seal	Window/s Seal	Electrical Leads-Trunk	Parcel Shelf	Parcel Shelf Seal	Trunk Seal	Holes in Spare Wheel Well	Unused Mounting Holes in Trunk	Black Deposit on Rear Bumper	Short Exhaust Tail Pipe	
Taxi Cab and Police Car	T-2-A-616	X		X									X	X						
	T-2-A-67		X				X							X						
	T-2-A-79		X	X			X	X					X	X						
	T-2-A-59			X									X	X	X			X	X	
	T-1-A-685		X	X	X		X	X	X	X	X	X	X	X	X	X	X			
	P-1-A-358			X		X					X	X	X		X			X		
	P-1-A-310	X		X								X	X							

*Severe

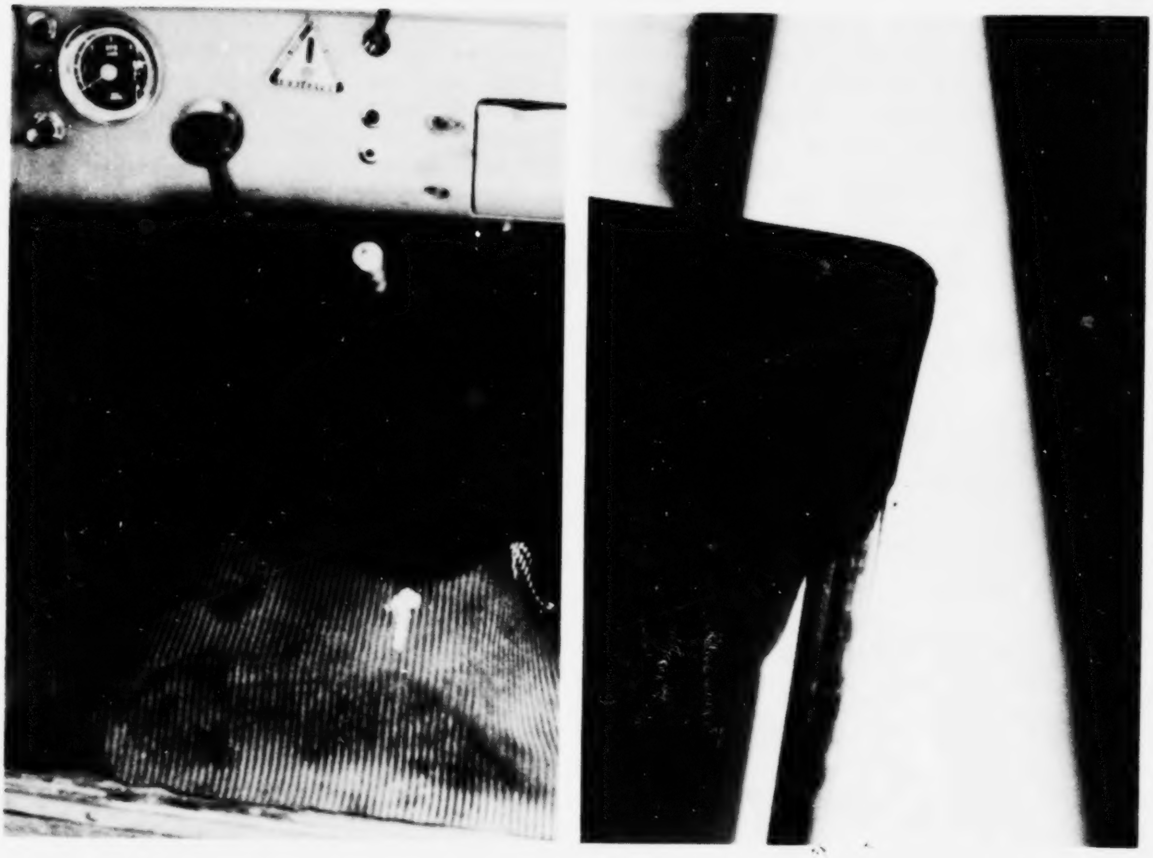
was not adjusted to bring up the seal snugly. This is important since the main release of exhaust from the exhaust system is outlet at the rear, quite close to this potential seal intrusion pathway through the emergency door seal.

Inspection results for the taxi cabs and police cars show similar results for the driver area as for the school buses. The partition between the passenger compartment and the trunk appear to provide almost no barrier to the flow of gases due to a number of openings such as unused speaker openings, electrical wire openings and the generally poor sealing around the parcel shelf and back seat. It appears, then, that if CO/exhaust gas can get into the trunk, it can fairly easily get into the passenger compartment. Therefore the important intrusion pathways to look for are those that would allow CO/exhaust gases to enter the trunk space itself. In several of the automobiles such pathways were found such as defective trunk seals and holes in the trunk floor. Some potential seal intrusion pathways identified by these inspection procedures are illustrated in Figures 4-15 and 4-16.

Results of the Tracer Tests for Intrusion Pathway Verification and Intrusion Process Characterization

Intrusion pathways identified by tracer gas source simulation testing during idling and on-road operation are presented for school buses in Table 4-9 and for taxicabs and police vehicles in Table 4-10. For each of the vehicles, six individual tests were performed corresponding to the six combinations of vehicle operating condition and tracer release locations separately indicated from top to bottom of the tables. Intrusion pathways so identified are listed from left to right corresponding to locations from the front to the rear of the vehicles. In general, as can be expected, the change from idling operation to on-the-road operation causes a shift from a situation where most of the active intrusion points are near the front of the vehicle to a situation where they are at the rear of the vehicle. In a similar manner, CO source locations (simulated by tracer release) at the front of the vehicle (such as at the engine exhaust manifold) results in more active intrusion through front openings as compared to CO source locations (simulated by tracer release) at the rear of the vehicle which results in a more active intrusion through the rear intrusion pathway (emergency door seals).

During each of the six individual tracer tests performed on each vehicle, the steady-state tracer concentration at the front and rear (trunk for automobiles) of the vehicles was measured. This value, when normalized by dividing by the tracer release rate and release concentration, results in what is called a transfer function. This might more appropriately be thought of as a response function to avoid confusion with formal mathematical use of the term "transfer function." Large values of the transfer function indicate that the transfer of CO between a source location and the vehicle interior is easy and rapid. Correspondingly, low values of the transfer function indicate that it is difficult for CO released at a given source to enter the passenger compartment. The transfer function, then, is a useful parameter for comparison of the effects of CO releases/leaks from different locations and under different operating conditions. The measured vehicle intrusion transfer functions at front and rear locations for each of the six tracer tests per



Figures 4-15 and 4-16. Two Potential Intrusion Points Identified in a School Bus: (1) a Damaged Protective Rubber Boot Around the Emergency Brake, (2) a Seal in a Poor Condition Around the Rear Emergency Door

Table 4-9

Carbon Monoxide Intrusion Pathways Identified In School Buses During Idling and On the Road** Operation. CO Source Simulation and Isolation by Tracer Release at 3 Locations Along the Exhaust System

				INTRUSION PATHWAYS							
Vehicle Type	Vehicle Operation	Tracer Release Location	Vehicle I.D.	Fire Wall Opening	Driver Foot Pedals /Floor	Windshield Washer Hose /Firewall	Emergency Brake Foot/Plate	Steering Column /Floor	Gear Shift Plate/Boot	Front Door Seal	Rear Emergency Door Seal
School Bus	Idling	Engine Manifold	B-5-A-405	X	X		X			X	
			B-5-A-211				X*	X*			X
			B-5-A-315	X			X			X	
			B-5-A-327				X				
			B-4-B-344					X	X		
			B-4-B-183				X	X			
		Mid Length of Exhaust System	B-5-A-405	X*			X*				
			B-5-A-211	X			X				
			B-5-A-315			X					
			B-5-A-327	X			X				
			B-4-B-344						X		
			B-4-B-183				X				X
		Exhaust Outlet	B-5-A-405				X				X*
			B-5-A-211				X			X	X*
			B-5-A-315				X			X	
			B-5-A-327								
			B-4-B-344					X	X		
			B-4-B-183				X	X			X
	On the Road	Engine Manifold	B-5-A-405	X			X			X	
			B-5-A-211	X			X				
			B-5-A-315			X				X	
			B-5-A-327				X				
			B-4-B-344					X			
			B-4-B-183				X				X
		Mid Length of Exhaust System	B-5-A-405								X*
			B-5-A-211							X	X
			B-5-A-315			X					X
			B-5-A-327								X
			B-4-B-344								
			B-4-B-183								X
		Exhaust Outlet	B-5-A-405							X	X*
			B-5-A-211				X				X
			B-5-A-315				X			X	
			B-5-A-327								
			B-4-B-344					X			X*
			B-4-B-183								X

*Severe

**Principally Urban Driving Routes

Table 4-10

Carbon Monoxide Intrusion Pathways Identified in Taxi Cabs and Police Cars During Idling and On the Road** Operation. CO Source Simulation and Isolation by Tracer Releases at 3 Locations Along the Exhaust System

				INTRUSION PATHWAYS				
Vehicle Type	Vehicle Operation	Tracer Release Location	Vehicle I.D.	Driver Foot Pedals	Steering Column /Floor	Fan Outlet (at on Position)	Back Seat/ Floor	Parcel Shelf
Taxi-Cab and Police Car	Idling	Engine Manifold	T-2-A-616					
			T-2-A-67		X*			X
			T-1-A-685					X*
			P-1-A-358		X	X	X	
			P-1-A-310				X	
		Mid Length of Exhaust System	T-2-A-616	X			X	
			T-2-A-67		X*		X*	
			T-1-A-685					
			P-1-A-358		X		X	
			P-1-A-310		X	X	X	
		Exhaust Outlet	T-2-A-616				X	
			T-2-A-67	X			X	
			T-1-A-685					X*
			P-1-A-358		X		X	X
			P-1-A-310			X	X	X
	On the Road	Engine Manifold	T-2-A-616	X				
			T-2-A-67		X*			
			T-1-A-685	X				
			P-1-A-358		X			X
			P-1-A-310		X	X		X
		Mid Length of Exhaust System	T-2-A-616				X	
			T-2-A-67		X			
			T-1-A-685	X				X*
			P-1-A-358					X
			P-1-A-310					
		Exhaust Outlet	T-2-A-616					X
			T-2-A-67		X			X
			T-1-A-685					X*
			P-1-A-358			X		X
			P-1-A-310			X		

*Severe

**Principally Urban Driving Routes

Table 4-11

Carbon Monoxide Intrusion Transfer Function* During Idling Operation in School Buses, Taxi-Cabs and Police-Cars. CO Source Simulation and Isolation by Tracer Releases at 3 Locations Along Exhaust System

TRACER GAS RELEASE LOCATION:		Engine Manifold		Mid Length Exh. System		Exhaust Outlet	
TRACER GAS DETECTION LOCATION:		Front	Rear/Trunk	Front	Rear/Trunk	Front	Rear/Trunk
Vehicle Type	Vehicle I.D.						
School Bus	B-5-A-405	660	540	21	14	24	11
	B-5-A-211	880	570	130	80	3	4
	B-5-A-315	7000	5800	5900	3300	1600	390
	B-5-A-327	6200	500	1600	280	NA	NA
	B-4-B-344	NA	NA	2300	2300	860	860
	B-4-B-183	5800	5800	2900	2900	840	840
Taxi-Cab/ Police Car	T-2-A-616	1000	550	950	800	120	96
	T-2-A-67	3600	3600	520	620	230	230
	T-1-A-685	18,900	18,900	2800	2800	1100	1100
	P-1-A-358	18,300	10,500	3400	2200	1300	1300
	P-1-A-310	3000	3400	9800	9800	3000	3000

*$\left(\frac{\text{min}}{\text{liter}}\right) * 10^{11}$

Table 4-12

CO Intrusion Transfer Function* During On the Road Operation in School Buses, Taxi-Cabs and Police-Cars. CO Source Simulation and Isolation by Tracer Releases at 3 Locations along Exhaust System

TRACER GAS RELEASE LOCATION:		Engine Manifold		Mid Length Exh. System		Exhaust Outlet	
TRACER GAS DETECTION LOCATION:		Front	Rear/Trunk	Front	Rear/Trunk	Front	Rear/Trunk
Vehicle Type	Vehicle I.D.						
School Bus	B-5-A-405	15	16	15	39	6	19
	B-5-A-211	450	260	17	37	3	24
	B-5-A-315	4700	4700	1800	2100	250	1500
	B-5-A-327	8600	2300	800	1100	NA	NA
	B-4-B-344	590	590	220	220	350	400
	B-4-B-183	2400	2400	700	700	220	330
Taxi-Cab/ Police Car	T-2-A-616	690	690	150	150	39	110
	T-2-A-67	560	580	110	120	82	57
	T-1-A-685	380	380	790	790	310	640
	P-1-A-358	2300	2300	1000	100	180	310
	P-1-A-310	1800	1800	150	1200	140	140

*$\left(\frac{\text{min}}{\text{liter}}\right) * 10^{11}$

Figure 4-17

Transfer Function Distribution at Three Simulated Carbon Monoxide Release Locations for School Buses

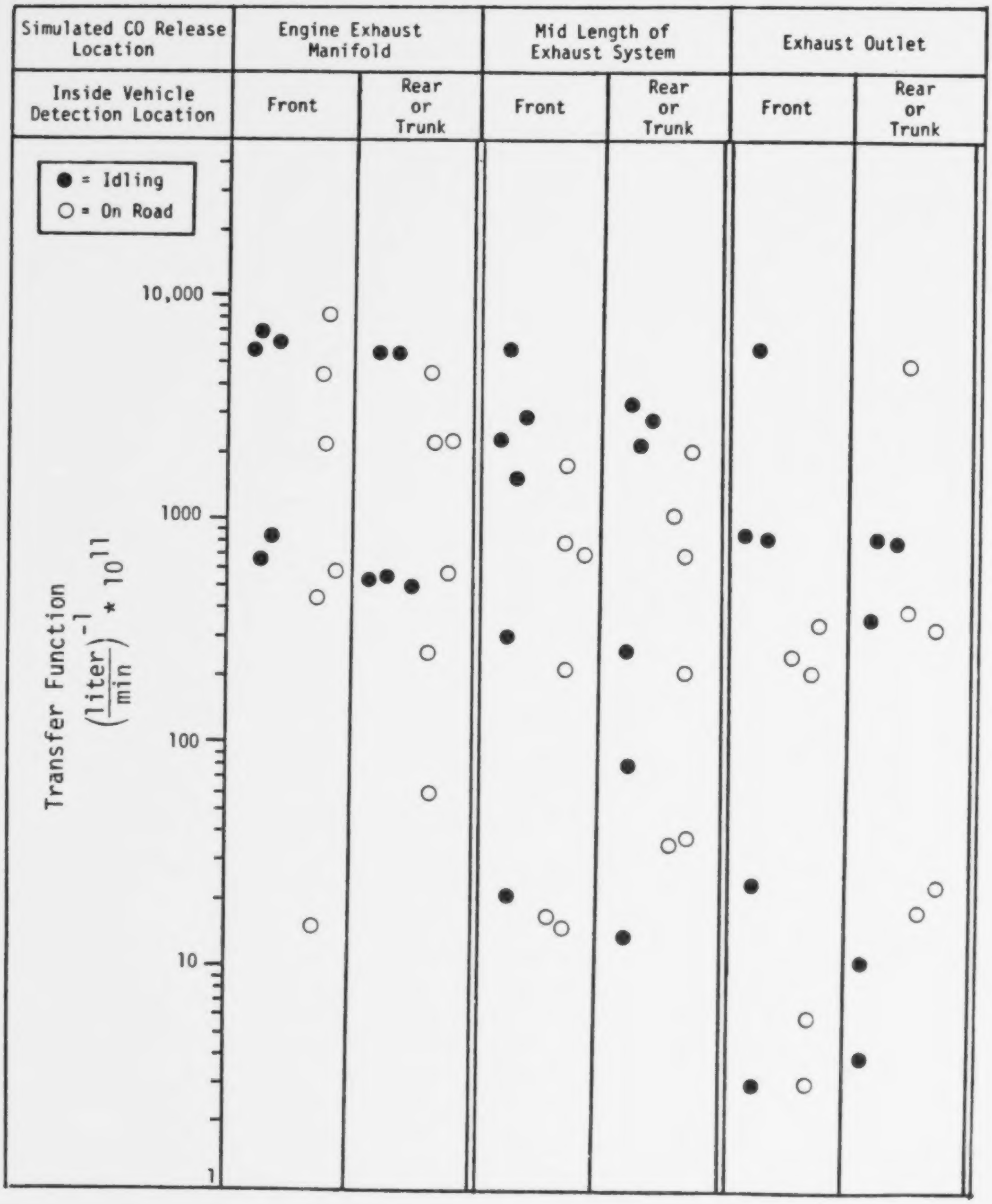
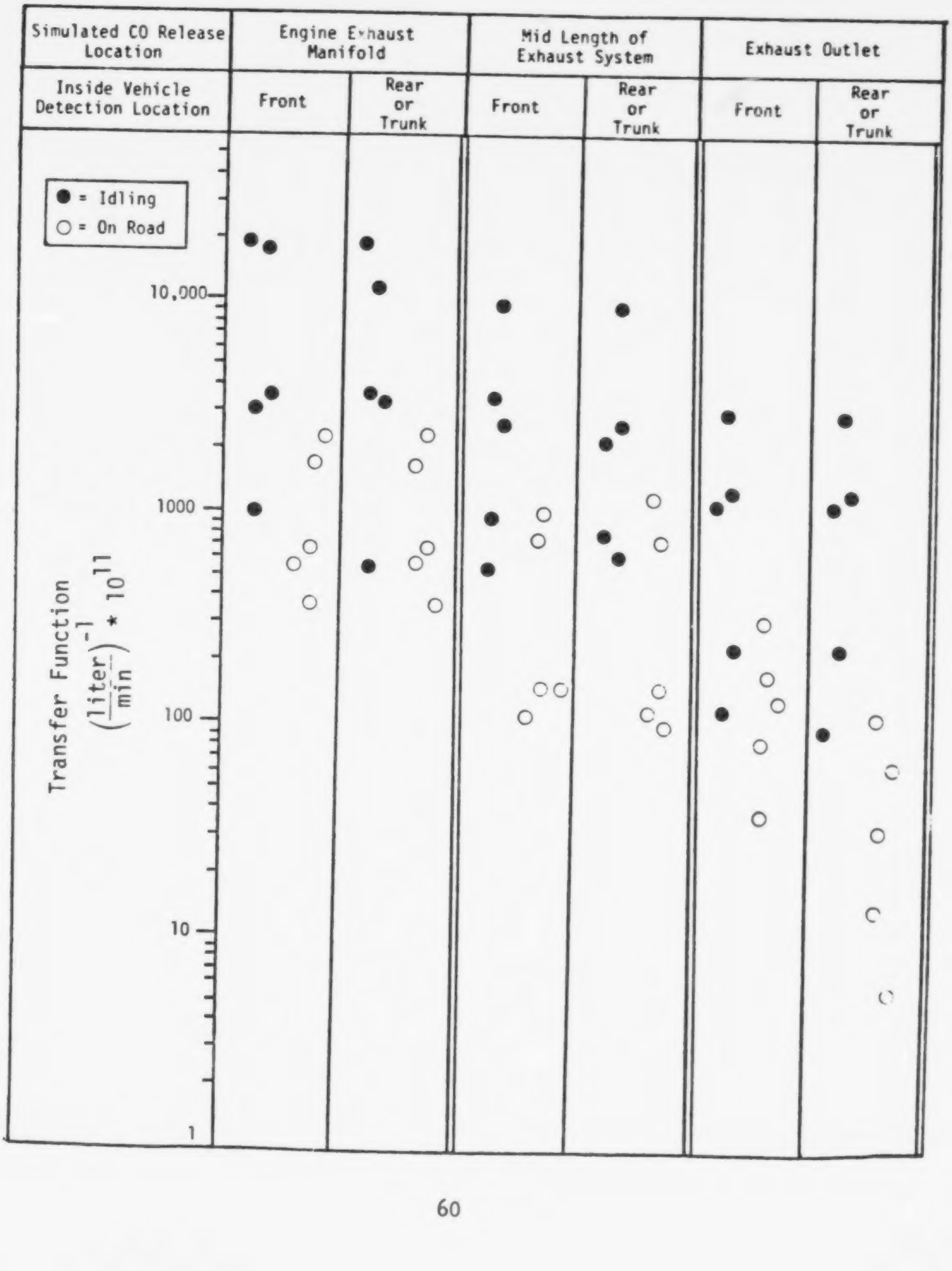


Figure 4-18

Transfer Function Distribution at Three Simulated Carbon Monoxide Release Locations for Taxi-Cabs and Police Cars



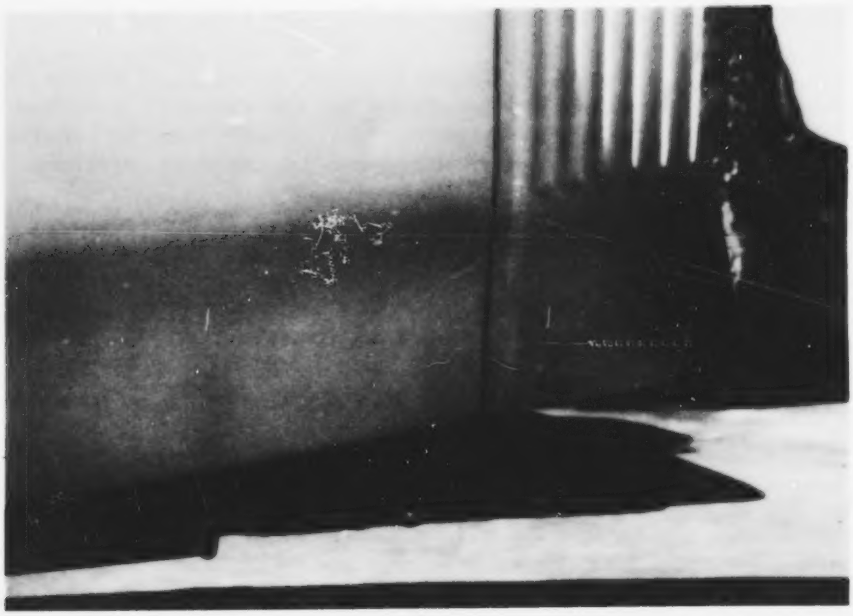
vehicle are presented in Table 4-11 for idling conditions and in Table 4-12 for on-the-road operating conditions. The tables are arranged as before by the release location (engine manifold, mid length of exhaust system, and exhaust outlet), and by the sampling locations in the front or rear/trunk. As can be expected, values are somewhat higher for idling than for on-the-road operation. These results are further discussed in the next section.

In order to further illustrate the transfer function results of the tracer test sequences, the transfer function values from Tables 4-11 and 4-12 have been plotted in tabular fashion for school buses on Figure 4-17 and for taxi cabs and police cars on Figure 4-18. The arrangement of the columns from left to right is again for release locations from the front of the vehicle to the rear. And, for each release location, the values of the transfer function for the front and rear/trunk of the vehicle are indicated.

Transfer functions for idling operation are indicated by solid circles and those for on-the-road operation by open circles. As can be seen for both school buses and automotive vehicles, transfer functions for idling operation are generally higher than for on-the-road operations, indicating that higher CO concentrations can be expected for idling operations than for on-the-road operations.

For both school buses and for automotive vehicles, and for both idling and on-the-road conditions for both, there is a general trend in the data diagonally from upper left to lower right. This general trend indicates, as expected, that for the same rate CO leak, the further toward the front of the vehicle the leak, the higher the resulting interior CO levels. This is to be expected since CO released near the front of the vehicle (for example at the exhaust manifold) is relatively close to, and has available the intrusion pathways at the front driver area of the vehicle whereas CO released at the rear portions of the exhaust system is less likely to enter through front intrusion pathways, particularly during on-the-road operation. It must be remembered, of course, that all these transfer functions correspond to interior levels achieved for the same CO release rate. Of course, the CO release rate from the exhaust outlet is much higher than the release expected through any leak in the exhaust system. However, it should be noted that the range in transfer functions tabulated in Tables 4-11 and 4-12 and correspondingly plotted in Figures 4-17 and 4-18, is very large (nearly 4 orders of magnitude for each vehicle type). This indicates that an exhaust leak at a forward location with an intrusion pathway nearby may have much more severe results than CO released from the exhaust outlet at a much greater rate.

Several other design characteristics or vehicle conditions which may influence transfer functions are shown on Figures 4-19 through 4-25. These include short tailpipe location and/or orientations (Figures 4-19 and 4-20); gaps in rubber sealing separating the engine area from the fresh air intake (Figure 4-21); abscence of rubber seal on the windshield bottom (Figure 4-22); holes in taxicab trunk (Figure 4-23); gaps in underbody sheet metal (Figure 4-24); muffler coupling leaks (Figure 4-25);



Figures 4-19 and 4-20. Tailpipe Configurations Favoring Intrusion

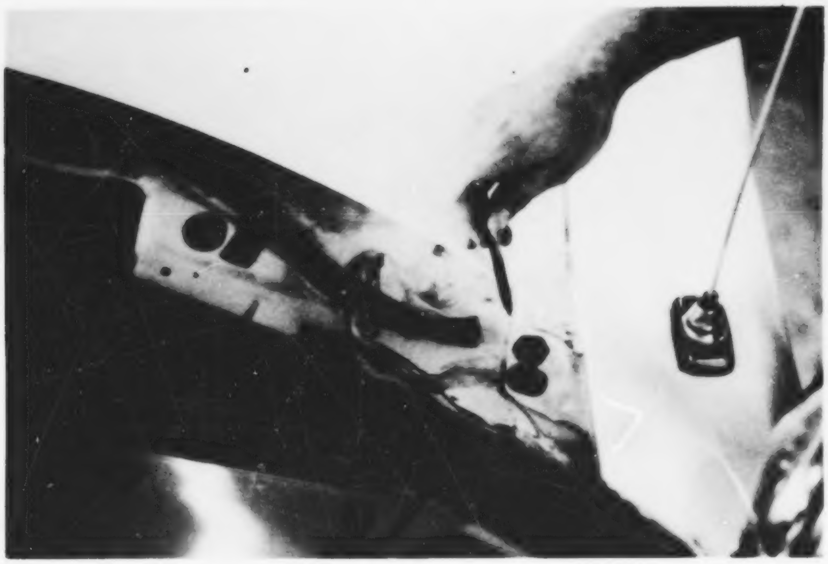


Figure 4-21. Engine Compartment Seal Gap

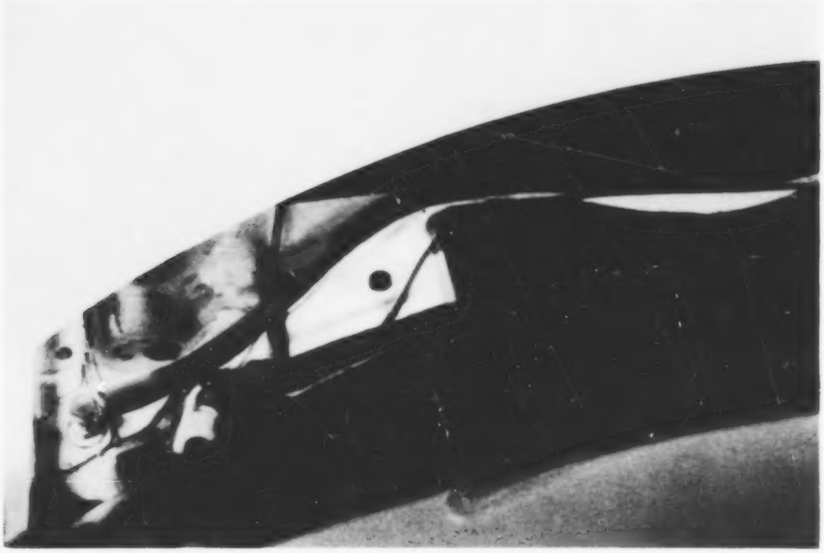


Figure 4-22. Missing Seal at Windshield Bottom

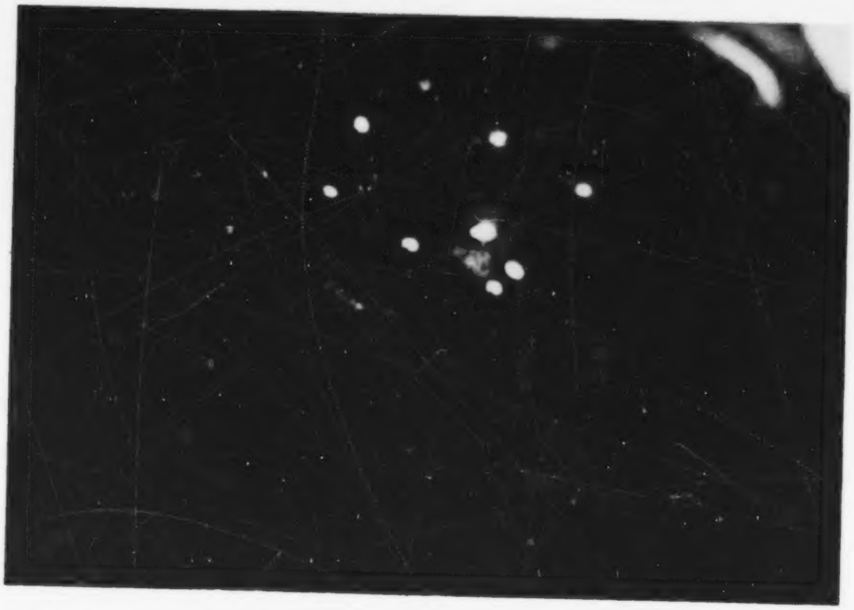


Figure 4-23. Holes in a Taxicab Trunk

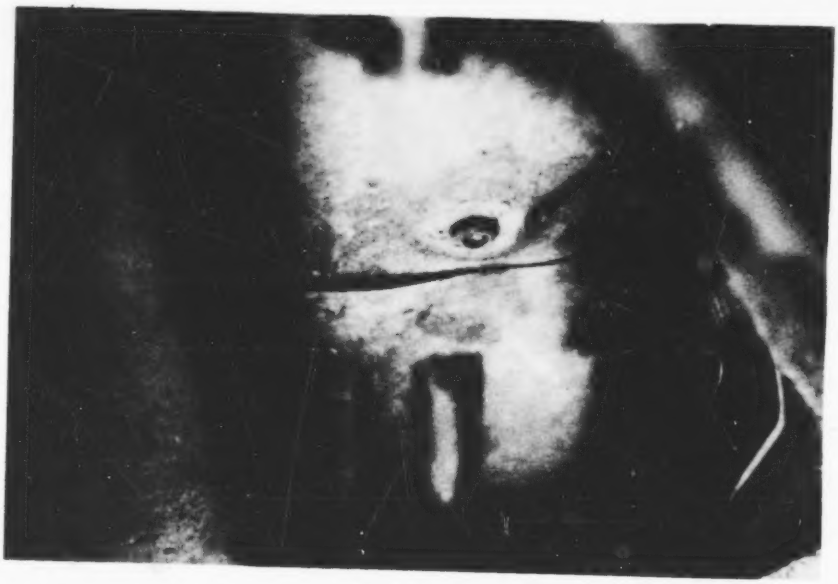


Figure 4-24. Sheet Metal Junction Gap in Vehicle Underbody

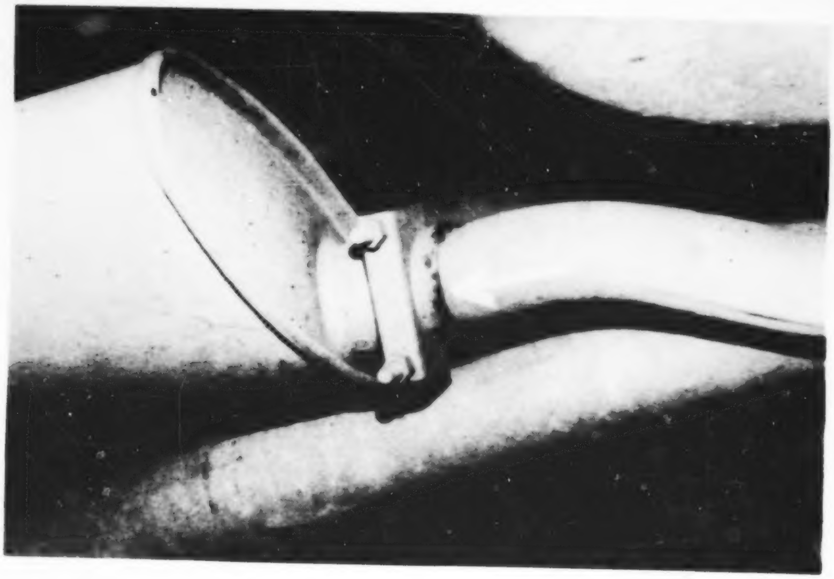


Figure 4-25. Coupling Leak at Muffler

VEHICLE CASE STUDIES

Each of the 24 vehicles that were evaluated during the special testing is discussed on the following pages. The inspection data are summarized along with all available CO and SF_6 results. Since all were considered for special testing, there was at least one piece of information gathered which brought the vehicle to our attention. As discussed previously, the objective of the final testing segments was either to (1) identify and isolate the factors responsible for observed elevated CO or (2) to quantitatively determine the importance of factors hypothesized to influence CO concentration in the vehicle.

School Bus B-5-A-115

Description--

1977 International Model 1703, 2 door, 37', 63 passengers, V-8, 345 cubic inch gasoline engine, automatic, front engine

Condition--

Very good, wear noted only at front door

Usual Route--

Urban, but not heavily congested, no tunnels on route

Rationale for Special Testing--

Difference front to rear on glass tube readings

Measurements Taken--

Glass Tube: 20 ppm average over nine hours in front; 3 ppm in rear

Personal Samplers: 4 ppm and 5.5 ppm average readings for two separate times

Continuous Analyzer: Interval levels did not ascend but rather reflected external events such as traffic

Exhaust test for CO leakage: Leaks confirmed at 6 points along exhaust system; several at rear of muffler and points along length

Intrusion Pathways - Visual Identification: Several observed by eye in front and rear but no large openings communicating directly to leak locations

Intrusion Pathways - Tracer Confirmation: N/D*

Intrusion Transfer Function(Maximum): N/D

Conclusions: The presence of severe leaks in the exhaust system is mitigated by the absence of critical intrusion pathways. This relatively new vehicle (∿ 20,000 miles) has the potential to cause significant problems by interior CO if pathways develop with age.

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*N/D = not determined(test never performed)

School Bus B-5-A-123

Description--

1977 International Model 1703, 2 door, 37', 63 passenger, V-8 345 cubic inch gasoline engine, automatic, front engine

Condition--

Very good except tailpipe rusting and uncombusted fuel observed in the exhaust

Usual Route--

Urban; not downtown or through tunnels

Rationale for Special Testing--

The uncombusted fuel observed might indicate poor state of tune with concomitant elevated CO

Measurements Taken--

Glass Tube: 2 ppm average over nine hours in front; 9 ppm in rear

Personal Samplers: N/D

Continuous Analyzer: N/D

Exhaust Test for CO Leakage: Leaks confirmed at the manifold to head pipe and the exhaust pipe to muffler connections

Intrusion Pathways - Visual Identification: Five pathways observed including possible critical ones at the gearshift boot and emergency brake

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function(Maximum): N/D

Conclusions--

In the presence of only the glass tube data, it is not possible to determine if the combination of verified CO leakage and intrusion points will cause CO problems in the vehicle. The observed rear door seal problem may have been responsible for the elevated rear to front readings.

School Bus B-5-A-211

Description--

1977 International Model 1703, 2 door, 37', 63 passenger, V-8, 345 cubic inch gasoline engine, automatic, front engine

Condition--

Rear tailpipe and clamp has been replaced in order to correct rusting; no obvious intrusion pathways; rusting observed at the time of special testing forward of replaced tailpipe section

Usual Route--

City route with fairly light traffic

Rationale for Special Testing--

Elevated front to rear glass tube

Measurements Taken--

Glass Tube: 23 ppm average over nine hours in front; 3 ppm in rear

Personal Samplers: N/D

Continuous Analyzer: The outdoor concentration of CO was light along the route with interior levels generally also low(< 5 ppm)*

Exhaust Test for CO Leakage: Numerous leaks with most severe at the rear end of the exhaust system

Intrusion Pathways - Visual Identification: Four pathways observed - three in the front plus the emergency door seal

Intrusion Pathways - Tracer Confirmation: The most significant source/pathway combination was released during idling from the manifold area and intrusion through the emergency brake foot and the steering column; another significant combination - rear exhaust release and emergency seal transfer

Intrusion Transfer Function(Maximum)--

Value of 880 for engine manifold release/front detection idling and 450 during on-the-road

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*Possible malfunction of interior channel suspected responsible for abnormally low readings.

Conclusions--

Although the transfer functions were not exceptionally high, it is clear that leakage in the front-most part of the exhaust system will easily intrude into the vehicle. This vehicle, although with quite low mileage, has the potential for developing seriously elevated CO levels inside. The elevated front to rear glass tube ratio is directly explainable.

School Bus B-5-A-314

Description--

1977 International Model 1703, 2 door, 37', 63 passengers, V-8, 345 cubic inch gasoline engine, automatic, front engine

Condition--

Tailpipe very rusty and nearly disassembling upon handling; no intrusion points obvious

Usual Route--

Relatively light urban traffic

Rationale for Special Testing--

The rear glass tube reading was both elevated and dissimilar from the front

Measurements Taken--

Glass Tube: 10 ppm average over approximately nine hours in front; 32 ppm in the rear

Personal Samplers: N/D

Continuous Analyzer: N/D

Exhaust Test for CO Leakage: Leaks confirmed at the junctions of head pipe to exhaust and at exhaust pipe to muffler

Intrusion Pathways - Visual Identification: Four locations observed- lid of engine compartment, heater/windshield water hose, gear shift boot, emergency door seal

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function(Maximum): N/D

Conclusions--

The combination of a very poor tailpipe condition, emergency door seal degradation, and elevated rear glass tube values appeared to be linked.

School Bus B-5-A-315

Description--

1977 International Model 1703, 2 door, 37', 63 passengers, V-8, 345 cubic inch gasoline engine, automatic, front engine

Condition--

Appears good to visual inspection; no intrusion points obvious

Usual Route-

Light to moderate urban route

Rationale for Special Testing--

The dissimilarity of front to back glass tube levels

Measurements Taken--

Glass Tube: 7 ppm average air approximately nine hours in the front; 22 ppm in the rear

Personal Samplers: N/D

Continuous Analyzer: N/D

Exhaust Test for CO Leakage: Severe leak verified at the junction of the manifold to head pipe, leak at exhaust pipe to muffler junction

Intrusion Pathways - Visual Identification: Three observed - the firewall, gearshift boot, and the emergency door seal

Intrusion Pathways - Tracer Confirmation: A number of pathways confirmed SF_6 infiltration both during idling and on-the-road operation; several pathways not visually observed were found to be significant: Emergency brake plate, front door seal

Intrusion Transfer Function(Maximum): Very high transfer functions coupling engine manifold leak area and mid length underbody leak location with both front and rear interior locations

Conclusions--

The tracer tests confirm that this vehicle has both CO sources and leakage pathways which might combine to create high CO levels in normal use. The moderate traffic route, low total mileage (23,000) and small mileage interval since tuneup(335)may be the mitigating factors.

School Bus B-5-A-320

Description--

1977 International Model 1703, 2 door, 37', 63 passenger, V-8, 345 cubic inch gasoline engine, automatic, front engine

Condition--

Tailpipe rusted and end decomposed; floor boards seem sticky

Usual Routes--

Moderate traffic, urban route, no tunnels

Rationale for Special Testing--

To evaluate the cause of the rear glass tube reading

Measurements Taken--

Glass Tube: 10 ppm average over approximately nine hours in front; 32 ppm in the rear

Personal Samplers: N/D

Continuous Analyzer: The interior reading is relatively isolated and damped(lower)than the exterior; no accumulation inside

Exhaust Test for CO Leakage: Significant leaks detected at the exhaust pipe/muffler junction and the muffler/tail pipe junction

Intrusion Pathways - Visual Identification: Four observed - two forward(engine compartment cables, heater hose)and two rear (missing screws under seats; emergency door)

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function(Maximum): N/D

Conclusion--

The severe leaks coupled with the rear intrusion points are the hypothesized links to explain the elevated glass tube readings. This vehicle has low mileage(24,000)and a recent tuneup(340 miles). Therefore, a problem could develop at some future point.

School Bus B-5-A-327

Description--

1977 International Model 1703, 2 door, 37', 63 passenger, V-8, 345 cubic inch engine, automatic, front engine, gasoline

Condition--

Appears good, rear clamp for exhaust system is loose

Usual Routes--

Rationale for Special Testing--

The rear glass tube reading is high and the intrusion path and source unknown

Measurements Taken--

Glass Tube: 7 ppm average over approximately nine hours in the front, 23 ppm in the rear

Personal Samplers: N/D

Continuous Analyzer: N/D

Exhaust test for CO leakage: Four leak points - three severe - junctions head pipe/exhaust, exhaust pipe/muffler, muffler/tail pipe

Intrusion Pathways - Visual Identification: A large opening at the emergency brake housing and four others

Intrusion Pathways - Tracer Confirmation: There is extremely efficient transfer through the emergency brake plate from the front and mid body sources

Intrusion Transfer Function(Maximum): The transfer function from engine manifold source to the front detector location is 6,200 and 8,600 for idling and on-the-road respectively

Conclusion--

The observations do not explain the elevated rear glass tube readings but instead point out the potential for CO intrusion from frontal sources and through the emergency brake plate

School Bus B-5-A-405

Description--

1977 International Model 1703, 2 door 37', 63 passenger, V-8, 345 cubic inch gasoline engine, automatic, front engine

Condition--

Appears in good condition

Usual Route--

Urban route with moderate traffic

Rationale for Special Testing--

To determine the cause of the elevated glass tube reading in the front

Measurements Taken--

Glass Tube: 26 ppm average over approximately 9 hours in front; 7 ppm in rear

Personal Samplers: N/D

Continuous Analyzer: The interior readings did not couple closely with the exterior nor were either very high

Exhaust Test for CO Leakage: Two locations found; both front (engine exhaust manifold and head pipe to exhaust pipe)

Intrusion Pathways - Visual Identification: Three of the four observed were in the front including steering column and mechanical cable links from the engine

Intrusion Pathways - Tracer Confirmation: There were a number of leak pathways verified, including five severe cases, for various source locations under idling and on-the-road conditions

Intrusion Transfer Function (Maximum): The transfer function values were small with the largest values during idling coupling engine manifold source location to the interior through a combination of four frontal intrusion points

Conclusions--

This vehicle showed a great number of intrusion pathways and two frontal leak sources. Under slow traffic or idling conditions, there may be problems with CO intrusion which were not present under steady movement routes

School Bus B-4-A-183

Description--

1966 Ford, V-8 gasoline front engine, 33', 66 passenger, approximately

188,000 miles with 9,000 since last tuneup

Condition--

Observed a hole at the emergency brake

Usual Route--

Rationale for Special Testing--

The elevated glass tube reading and the results of continuous analyzer testing pointed out a potentially serious intrusion condition

Measurements Taken--

Glass Tube: 45 ppm average over an 11 hour period in the front of the bus

Personal Samplers: N/A

Continuous Analyzer: Frequently observed elevated interior levels (over exterior); while moving the interior levels build up and become 15 ppm above exterior; when buses stop the levels inside tend to decrease (whether engine on or off)

Exhaust Test for CO Leakage: Leakage verified at two forward locations: (1) junction manifold to head pipe (2) the head pipe to exhaust pipe

Intrusion Pathways - Visual Identification: Eight pathways were identified, including unusual condition of firewall seal area

Intrusion Pathways - Tracer Confirmation: The verified pathways which appeared most often were the emergency brake foot, steering column, and the rear emergency door

Intrusion Transfer Function (Maximum): Transfer coefficients were largest during idling with an engine manifold source (5,800)

Conclusion--

This vehicle is of concern. It has exhibited a high degree of CO intrusion through frontal pathways. High mileage may be responsible for the existence of both sources and pathways. Corrective action is advised.

School Bus B-4-A-342

Description--

1975 Ford, V-8 gasoline front engine, 33', 66 passenger, approximately 80,000 miles with 2,000 since last tuneup, forced air ventilation

Condition--

Appears good

Usual Route--

Rationale for Special Testing--

High glass tube values in addition to interior levels exceeding exterior during continuous analyzer run

Measurements Taken--

Glass Tube: 33 ppm average over 9 hours in front

Personal Samplers: N/D

Continuous Analyzer: Interior levels almost always higher except when exterior peaks due to close traffic; heater was on and windows closed; highest interior levels (∿20 ppm) observed when the heater blower was turned on

Exhaust Test for CO leakage: Two locations observed (1) manifold/head pipe (2) muffler/tail pipe

Intrusion Pathways - Visual Identification: Three observed were mechanical connections from the engine compartment, steering column base, and the emergency door seals

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function (Maximum): N/D

Conclusions--

Interior levels exceed the exterior by difference of 5-10 ppm. It is felt that evidence of intrusion pathways and the confirmed CO leak locations are responsible for the intrusion.

School Bus B-4-A-344

Description--

1975 International Blue Bird, V-8 gasoline engine, 33', 66 passenger, forced air ventilation, 85,500 total miles with 9,000 since last tune-up

Condition--

Appears good

Usual Route--

Rationale for Special Testing--

To investigate elevated glass tube reading

Measurements Taken

Glass Tube: 51 ppm average over approximately 9 hours in front

Personal Samplers: N/D

Continuous Analyzer: The average interior level exceeded the fluctuating exterior; there appears to be little coupling between interior and exterior readings; windows closed

Exhaust Test for CO Leakage: Severe leaks at three locations - engine exhaust manifold, manifold/head pipe junction, muffler/tail pipe junction

Intrusion Pathways - Visual Identification: Four observed; three frontal - mechanical cable penetrations from engine compartment, heater/windshield water hose, steering column base;one rear - emergency door seal

Intrusion Pathways - Tracer Confirmation: Two distinct combinations were confirmed - the steering column base or gear shift boot pathways with nearly any tracer source location(both idling and road) and a severe pathway through the emergency door seal for the on-the-road test and rear tracer release

Intrusion Transfer Function(Maximum): Transfer coefficients were of low to medium value(229-2,800)

Conclusions--

The extremely high glass tube data was consistent with the elevation of internal over external level found during the continuous sampling measurements. The elimination of exhaust manifold leaks appears to be important to correct this problem as does sealing the intrusion pathways. Tuneup interval doesn't appear to be the controlling factor.

School Bus B-4-A-355

Description--

1975 Ford, V-8 gasoline engine,33', 66 passenger, forced air ventilation, 81,500 total miles with 9,000 since last tuneup

Condition--

Appears good

Usual Route--

Rationale for Special Testing--

Elevated glass tube reading and isolated peaks during continuous analyzer monitoring

Measurements Taken--

Glass Tube: 50 ppm average over 9 hours in front

Personal Samplers : N/D

Continuous Analyzer: Interior and exterior levels generally averaged the same, interior fairly low; several unexplainable intermittent peaks inside up to 50 ppm

Exhaust Test for CO leakage: Severe leaks at the exhaust manifold and the junction of the manifold to the head pipe; leak at the junction muffler/tail pipe

Intrusion Pathways - Visual Identification: Five identified(engine compartment bed, mechanical cable penetrations from engine compartment, steering boot, stuck window, emergency door seal)

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function(Maximum): N/D

Conclusions--

The central stuck window seems to assure ambient ventilation which may be responsible for the **absence** of a more severe level. Front levels were higher during the continuous monitoring. The front sources may be controlling the intrusion.

School Bus B-3-A-28

Description--

1976 International, V-8, 392 cubic inches,33', 55 passenger, 35,800 total miles with 4,000 since last tuneup

Condition--

Appears good

Usual Route--

Begins at residential and proceeds to downtown

Rationale for Special Testing--

Glass tube and continuous analyzer readings considerably above the fixed station ambient and exterior levels

Measurements Taken--

Glass Tube: 39 ppm average over approximately 10 hours as measured by separate tubes front and rear

Personal Samplers: N/D

Continuous Analyzer: Interior consistently exceeded exterior (except when analyzer location was moved in the proximity of the exhaust plume). Interior peaks of 25 ppm

Exhaust Test for CO Leakage: Five leak locations found across front to rear

Intrusion Pathways - Visual Identification:

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function (Maximum): N/D

Conclusions--

Confirmation of elevated interior levels was made by glass tube and continuous analyzer measurements. Leaks observed were considered sufficient to be responsible for CO levels.

School Bus B-3-A-83

Description--

1974 Ford, V-8, 345 cubic inch gasoline engine, 37', 78 passengers, 93,000 total miles with 5,000 miles since tuneup, dual exhaust system

Condition--

Appears good

Usual Route--

Rationale for Special Testing--

High rear glass tube reading

Measurements Taken--

Glass Tube: 10 ppm average over ten hours in front and 79 ppm in rear

Personal Samplers: Questionable reading obtained

Continuous Analyzer: N/D

Exhaust Test for CO Leakage: Two locations: (1) front manifold/head pipe (2) head pipe/exhaust pipe

Intrusion Pathways - Visual Identification: Six identified, including missing screws under seats

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function (Maximum): N/D

Conclusions--

Unfortunately, not enough data was taken to confirm readings or develop clear reason. Missing screws under seats should be replaced and further tests run.

School Bus B-3-A-93

Description--

1970 Ford, V-8, 361 cubic inch, gasoline engine, 34', 60 passenger, 138,000 total miles with 19,000 since last tuneup

Condition--

Appears good

Usual Route--

Includes congested downtown area

Rationale for Special Testing--

Glass tube and continuous analyzer levels were elevated

Measurements Taken--

Glass Tube: 39 ppm average in both rear and front over approximately 9 hours

Personal Samplers: N/D

Continuous Analyzer: With windows closed on trip, the interior showed to be above exterior levels and rose gradually to a peak of 45 ppm compared to 20 ppm external

Exhaust Test for CO Leakage: None detected

Intrusion Pathways - Visual Identification: Five identified, including missing screws under seats, rear wheel well gaskets, and gear shift boot

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function (Maximum): N/D

Conclusions--

The analyzer ride taken showed that in the closed bus with heater on, the levels ascend with stop and start traffic. The corrective action indicated is to repair the intrusion pathways, remove this bus from downtown service, and tuneup the vehicle.

School Bus B-3-A-567

Description--

1974 International Bluebird, V-8, 392 cubic inches, 34', 66 passenger, 64,000 miles with 1,700 since tuneup

Condition--

Observed gear shift boot not sealed; holes at foot pedals; driver complains of fumes

Usual Route--

Includes downtown area

Rationale for Special Testing--

High glass tube readings and accumulation during windows closed on continuous analyzer tests

Measurements Taken--

Glass Tube: 37 ppm average front and rear over approximately nine hours

Personal Samplers: N/D

Continuous Analyzer: Windows closed are associated with elevation of the interior over exterior; during slow downtown traffic the interior levels reached their sustained peaks of up to 40 ppm with exterior levels of approximately 15 ppm

Exhaust Test for CO Leakage: Four leak sources: (1) manifold/head pipe (2) head pipe/exhaust pipe (3) exhaust pipe/muffler (4) muffler/tail pipe

Intrusion Pathways - Visual Identification: See above under condition

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function(Maximum): N/D

Conclusions--

This vehicle shows many CO leakage sources and several large pathways. Repairs and reassignment from downtown area are recommended.

Taxicab T-2-A-59

Description--

1977 Plymouth Fury, 80,000 miles, 6 cylinder, 225 cubic inches

Condition--

Worn and with signs of exhaust contamination

Usual Route--

Suburban; very light traffic

Rationale for Special Testing--

Glass tube readings exceeded the 9ppm 8 hour standard

Measurements Taken--

Glass Tube: 16 ppm average over approximately 9 hours both in front and in the back

Personal Samplers: N/D

Continuous Analyzer: N/D

Exhaust Test for CO Leakage: Leaks located at nearly every junction of the exhaust system; severe leaks at three locations - catalytic converter to exhaust pipe, exhaust pipe to muffler, and muffler to tailpipe

Intrusion Pathways - Visual Identification: Four pathways were observed-vent inlet seal, parcel shelf, parcel shelf seal, trunk seal. An area of carbon deposits was noted on the rear bumper; short exhaust tail pipe was observed.

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function(Maximum): N/D

Conclusions--

The condition of the vehicle was judged to be poor and offered sufficient reason for elevated CO interior levels. This taxicab is used in a relatively light traffic area, and this may be a mitigating factor.

Taxicab T-2-A-67

Description--

1976 Plymouth Valiant, slant 6 cylinder, 225 cubic inches, 120,000 miles

Condition--

Foot pedal floorboard area holes noted

Usual Route--

Suburbs to downtown alternating between light to heavy traffic

Rationale for Special Testing--

Large holes observed in foot pedal/steering column area

Measurements Taken--

Glass Tube: 8 ppm average front and 6 ppm rear over 7 hours

Personal Samplers: N/D

Continuous Analyzer: Peak levels exceeded 100 ppm both inside and outside; average levels inside and outside are comparable (20-23 ppm); fluctuations with time are rapid as the effects of immediate exterior ambient levels are noted

Exhaust Test for CO Leakage: Four leak locations observed in the exhaust system - engine exhaust manifold, head pipe to catalytic converter, muffler, muffler/tailpipe

Intrusion Pathways - Visual Identification: Three observed - engine compartment electrical connections, foot pedals, parcel shelf seal

Intrusion Pathways - Tracer Confirmation: Severe intrusion located through the steering column for nearly all tracer release positions

Intrusion Transfer Function (Maximum): The highest transfer function was during idling from an engine manifold source (3600)

Conclusions--

Traffic congestion is directly observed to cause elevated CO levels. At some red lights, both interior and exterior levels were > 100 ppm. This vehicle has a significant number of intrusion points, and communication between exterior and interior is rapid. This vehicle could be improved if intrusion pathways were closed.

Taxicab T-2-A-79

Description--

1977 Plymouth Fury, a slant 6 cylinder, 225 cubic inches, 80,000 miles

Condition--

Observed soot along exhaust system

Usual Route--

Suburbs to downtown/airport alternating between light to heavy traffic

Rationale for Special Testing--

Elevated glass tube levels

Measurements Taken--

Glass Tube: 17 ppm average in both the front and the rear during approximately 7½ hour trip

Personal Samplers: N/D

Continuous Analyzer: N/D

Exhaust Test for CO Leakage: Four leak sources including two severe ones at muffler and muffler/tailpipe

Intrusion Pathways - Visual Identification: Six pathways noted - engine compartment electrical lid, vent inlet seal, foot pedals, steering column, parcel shelf, and parcel shelf seal

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function(Maximum): N/D

Conclusions--

Significant source and intrusion pathways were noted which could develop high interior levels of CO under slow or heavy traffic conditions.

Taxicab T-2-A-616

Description--

1976 Plymouth Fury, slant 6 cylinder, 225 cubic inches, 120,000 miles

Condition--

Exhaust system condition generally poor

Usual Route--

Suburbs to downtown/airport alternating between light to heavy traffic

Rationale for Special Testing--

Observation of the exhaust system condition

Measurements Taken--

Glass Tube: N/D

Personal Samplers: N/D

Continuous Analyzer: N/D

Exhaust Test for CO leakage: Five sources measured - engine exhaust manifold, manifold to head pipe, exhaust pipe to muffler, muffler, and muffler to tailpipe

Intrusion Pathways - Visual Identification: Four noted - firewall, vent inlet seal, parcel shelf, and parcel shelf seal

Intrusion Pathways - Tracer Confirmation: Principal pathways were determined to be through the driver foot pedals and the back seat/ floor area

Intrusion Transfer Function(Maximum): The maximum value arose during idling when tracer was emitted from the manifold area and detected in the front(1,000)

Conclusions--

The intrusion pathways appear to be front and rear with the front leakage source playing perhaps the most important role.

Taxicab T-1-A-216

Description--

1976 Checker, Chevrolet 250 CID, gasoline, 6 cylinder, 199,000 total miles with 8,000 since tuneup

Condition--

Oily film around the rear seal and several intrusion and wear points observed

Usual Route--

Citywide with trips to and from downtown, airport, and suburbs

Rationale for Special Testing--

High glass tube reading and observation of oily film in rear

Measurements Taken--

Glass Tube: 54 ppm average over approximately 5 hours

Personal Samplers: N/D

Continuous Analyzer: N/D

Exhaust Test for CO Leakage: Five leak points measured- manifold/head pipe, head pipe/catalytic converter, catalytic converter/exhaust pipe, exhaust pipe/muffler, muffler

Intrusion Pathways - Visual Identification: Holes at floor pedal, rear parcel deck communicates to the trunk, door seals worn, trunk seals worn

Intrusion Pathways - Tracer Confirmation: N/D

Intrusion Transfer Function(Maximum): N/D

Conclusions--

A significant number of sources and intrusion pathways were found which would explain the elevated glass tube levels

Taxicab T-1-A-685

Description--

1974 Checker, Chevrolet 250 CID, 6 cylinder, 300,000 miles, 6,000 from tuneup

Condition--

Holes around gas pedal; trunk lid would not shut tightly; oily film around back seat; holes from back seat to trunk

Usual Route--

Includes downtown and airport areas

Rationale for Special Testing--

Elevated glass tube reading

Measurements Taken--

Glass Tube: 47 ppm average over approximately 8 hours

Personal Samplers: N/D

Continuous Analyzer: The front windows stayed open on both sides and interior values generally followed all the time trace characteristics of exterior trace and were slightly lower

Exhaust Test for CO Leakage: Six leak points located front to rear, with a severe leak at the muffler to tail pipe junction

Intrusion Pathways - Visual Identification: This vehicle had 14 intrusion points identified, far exceeding any other vehicle

Intrusion Pathways - Tracer Confirmation: The most severe pathway arose through the rear parcel shelf

Intrusion Transfer Function(Maximum): Values were exceptionally high with maximum occurring from an engine manifold leak location(18,900)

Conclusions--

This vehicle is potentially lethal. During the continuous analyzer ride, the windows were half opened, since it was warm. It is recommended that the conditions noted be corrected as soon as possible.

Police P-1-A-310

Description--

1978 Ford LTD, V-8, 4 door, gasoline engine

Condition--

Good condition to visual observation

Usual Route--

Adjacent to downtown area for patrol

Rationale for Special Testing--

Elevated glass tube and personal sampler readings

Measurements Taken--

Glass Tube: 17 ppm average over approximately 8 hours in the front

Personal Samplers: 29.9 ppm over 8 hours with ambient readings approximately 1.6 ppm in area

Continuous Analyzer: N/D

Exhaust Test for CO Leakage: Four points detected - exhaust manifold, catalytic converter to exhaust pipe, exhaust pipe to muffler, and muffler

Intrusion Pathways - Visual Identification: Four noted - firewall, vent inlet seal, electrical leaks to trunk, and parcel shelf

Intrusion Pathways - Tracer Confirmation: Several determined - back seat/floor, steering column/floor, parcel shelf, and air fan outlet when on

Intrusion Transfer Function(Maximum): The range of values tended to be high with the worst condition during idling from a mid underbody source(9800)

Conclusion--

This vehicle has several unique features including the CO level increase through the ventilation fan operation and the mid underbody tracer source being the highest transfer function. Sitting in this vehicle with engine idling resulted in > 100 ppm of CO. The fresh air intake may be communicating with engine emissions and the catalytic converters are leaking raw exhaust.

Police Car P-1-A-358

Description--

1978 Ford LTD, V-8, 4 door, gasoline engine, 19,000 miles with 10,000 since tuneup

Condition--

Visually good

Usual Route--

Patrols downtown

Rationale for Special Testing--

Elevated levels by all methods

Measurements Taken--

Glass Tube: 28 ppm and 86 ppm on two separate occasions of approximately 8 hours each

Personal Samplers: 38.8 ppm average over 8 hours with approximately 3.3 ppm fixed site ambient

Continuous Analyzer: In downtown area, the interior level exceeded exterior (30 ppm - 20 ppm); other times, the two were comparable; windows were often opened during test

Exhaust Test for CO Leakage: Three leaks: (1) manifold/head pipe (2) head pipe/catalytic converter (severe) (3) muffler

Intrusion Pathways - Visual Identification: Seven pathways identified including two at the front - vent inlet seal and front windshield seal

Intrusion Pathways - Confirmation: Four confirmed: (1) steering column floor,(2) back seat/floor,(3) parcel shelf, (4) the ventilation fan outlet (when on)

Intrusion Transfer Function (Maximum): During idling, all source locations produced large transfer functions (>1,000) with the engine manifold source yielding the maximum (18,300); similar hierarchy for the moving vehicle

Conclusions--

Sitting in this idling vehicle with windows closed and vent turned on resulted in > 100 ppm CO concentrations in several minutes. The design and leakage conditions of this vehicle have resulted in a serious intrusion problem which must be addressed.

SECTION 5

DISCUSSION OF RESULTS

COMMENTS ON PROCEDURES, INSTRUMENTATION, AND RESULTS

Program experience has indicated that passive stain tube cards are useful for surveying CO exposures in a large vehicle population. Although the devices could have been more easily read and thus more precise had their scales been expanded, they provided useful and inexpensive quantitative data. These data helped us to estimate fleetwide CO concentration exposure averages and were effective in discovering unusually elevated levels and conditions such as marked front-to-rear differences in exposure. Although they are not as precise as personal samplers or continuous analyzers, their requirements for maintenance, calibration, and personnel expertise are considerably lower.

It was anticipated that the personal sampler measurements would be more productive in developing CO survey data than they were. The primary difficulty was equipment unavailability due to outage and in-service failure. Additionally, although some instruments calibrated and humidified acceptably, statistical analyses of the survey results after repeated issuance revealed that several dosimeters differed in a systematic manner from a random distribution of concentration, i.e., tended to have a uniformly low or high reading despite random use. Finally, on some days an insufficient number of volunteers could be recruited either because smokers were being excluded or insufficient cooperation was obtained. One matter affecting the degree of cooperation was the fact that the sampler, although small, is comprised of two distinct devices- a pump and a dosimeter. It is felt that an integrated unit, if sufficiently compact, would seem less imposing. Furthermore, the incorporation of readout capability within the dosimeter rather than in a separate readout unit would offer certain advantages. If the single readout device fails in the field, the entire data set is lost. Finally, readings from an integrated unit could be taken during the field use period and at shorter time intervals.

The strongest tool to identify conditions accompanying the formation of higher inside than outside levels of CO was the continuous CO analyzer. Recorder traces of simultaneously measured interior and exterior levels were analyzed along with observations of analyzer location within the vehicle, operating conditions, traffic, and vehicle design. Both instantaneous concentrations and planimeter-derived averages were compared. This procedure explicitly separated out the influence of external ambient concentrations, allowing us to focus upon underlying CO intrusion mechanisms and conditions. Calibrating these devices daily and comparing readings at the same location (or with all the windows opened to obtain full equalization) were means taken to assure the validity of comparing readings and determining their differences.

The most powerful techniques were those used for the special testing-minute inspections of the vehicles to identify possible leaks and intrusion points and tracer gas testing to gauge the extent and direction of intrusion. Since these techniques require considerable expertise, resources and time (four hours per vehicle), they should be applied only after the simpler measurement efforts have identified potential problem vehicles.

DISCUSSION OF INTRUSION PATHWAYS AND LEAK SOURCES

Table 4-8 summarizes the potential carbon monoxide intrusion pathways identified by vehicle inspections. Sulfur hexafluoride (SF_6) tracer measurements were made in order to observe time dependent intrusion through postulated pathways. Table 4-9 illustrates that for school buses, severe intrusion pathways were verified at fire wall openings, emergency brake foot/plates, and rear emergency door seals. For taxicabs and police vehicles, severe pathways included steering column/floor, back seat/floor, and the rear parcel shelf.

CO monitoring procedures identified severe leak locations at a number of exhaust system junction points, as illustrated in Table 4-7. No one point was predominant. Although the transfer functions from leak source to the vehicle interior varied according to leak location, idle/on-the-road condition and interior detection location, their values were not sufficiently uniform as to ignore vehicle-to-vehicle variation. Figures 4-17 and 4-18 illustrate that highest transfer generally occurred from forward location sources during idling.

RELATION BETWEEN FIELD MEASUREMENTS AND FIXED SITE MONITOR DATA

As was pointed out in the presentation of measurement results, there was rarely any correspondence between the carbon monoxide concentrations detected in sustained-use vehicles and those measured by the fixed site monitoring stations closest to the study vehicles' routes of travel. In general, as Figure 4-11 illustrates, CO levels immediately outside the test vehicles were higher than those measured by the monitoring stations. As our continuous analyzer traces show, the study vehicles move through a constantly changing atmospheric environment. The magnitude and sign of the difference between inside and outside concentrations varies from second to second. Too little is known about intrusion kinetics to gauge the importance of the large but brief peak exterior concentrations observed in our tests. In order to ascertain the relation, if any, between fixed site data and actual exposures, a comprehensive program of vehicle monitoring, meteorological modeling, and fixed site data analysis is necessary.

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4. Ziskind, R., T. Carlin, et al. Carbon Monoxide Intrusion Into The Passenger Area of Sustained-use Motor Vehicles Literature Review/Pilot Study. Prepared by Science Applications, Inc., for Environmental Protection Agency, Environmental Monitoring Branch, Research Triangle Park,N.C. (Contract No. 68-02-2958), 1978.

APPENDIX A

EXPERIMENTAL PROCEDURE DATA SHEETS

It was crucial to standardize all data collection and quality assurance procedures in order to provide a basis for comparing the vehicle fleets and cities under study. To this end, a number of written procedures, data forms, and information sheets were used. Form A-1 was provided to all interested parties to briefly explain the purpose of the program. Stain tube cards were affixed to all vehicles immediately before drivers entered and started their vehicles. The notice Form A-2 was given to the driver of each instrumented school bus. Similar forms were provided to police and taxicab drivers. Data sheet Form A-3 was used to record glass stain tube dosimeter field data. Allowance was made (columns 4 and 5) for return of school bus vehicles during the midday break. Ambient CO in fleet terminals was measured with continuous analyzers in order to facilitate accounting for exposures during that period. Vehicle inspection forms as shown in Table 3-2 were completed. They included route information in order to identify fixed location monitoring site(s) whose concentrations were to be compared with or subtracted from the field measurements.

The initial step in the personal sampler phase was to recruit volunteers at each dispatch terminal. Form A-4 was issued to all drivers who responded favorably. At the same time drivers were issued personal samplers, they were given Form A-5 as a reminder. Personal sampler data were recorded on Form A-6. Columns 5 and 6 were used twice if the driver returned to the terminal, and the sampler was collected and reissued. Ambient CO (Column 11) was derived from fixed site monitoring location data.

Continuous analyzer information was taken directly onto recording traces and annotated on data sheet Form A-7. Figure A-1 shows a sample trace from a continuous analyzer. Both the interior and exterior CO concentrations are displayed. Approximately 40 minutes of elapsed time are covered. Conditions are annotated by letters A-E on both Figure A-1 and Form A-7 and described on the latter along with the corresponding time.

Form A-1

INFORMATION SHEET

Science Applications, Inc. (SAI) is conducting a study for the U.S. Environmental Protection Agency to determine the incidence and causes of elevated levels of carbon monoxide in school buses, taxis, and police cars. In achieving this objective, instruments are used which have no effect either on the vehicles or their occupants. SAI also needs to gather some information about each vehicle tested and their routes or areas of duty. Your cooperation and assistance is greatly appreciated.

Form A-2

IMPORTANT NOTICE TO SCHOOL BUS DRIVERS

Science Applications, Inc. (SAI) is conducting a study for the U.S. Environmental Protection Agency to determine the incidence and causes of elevated levels of carbon monoxide in school buses, taxis, and police cars. In achieving this objective, instruments are used which have no effect either on the vehicles or their occupants.

In this first stage of testing, air monitoring devices (which look like a 3" x 5" card with a glass tube attached) will be placed on school buses in two locations -- one under the rear seat and one near the driver. The device near the driver may be visible to the school children. Drivers are requested to prevent the children from tampering with the devices to the greatest extent possible.

Your cooperation and assistance is greatly appreciated.

Form A-3

DATE	SCIENCE APPLICATIONS, INC. DATA SHEET FLEET TESTING GLASS TUBE DOSIMETERS	PAGE OF
NAME OF FLEET		PREPARED BY
LOCATION OF DEPOT		

	(1) Veh. I.D. No.	(2) Sampler Loc.	(3) Start Time	(4) Morning Return	(5) Pickup Departure	(6) Finish Time	(7) Sampler Reading	(8) Elapsed Time	
1.									
2.									
3.									
4.									
5.									
6.									
7.									
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Form A-4

Science Applications, Inc. (SAI) is conducting a study for the U.S. Environmental Protection Agency (EPA) to determine the incidence and causes of elevated levels of carbon monoxide in school buses, taxis, and police cars. As part of this study, we are seeking volunteers to wear a small device known as a personal sampler, which measures the level of carbon monoxide to which you, as a driver, are exposed.

The sampler, which is about the size of a pack of cigarettes and weighs about 10 ounces, is clipped to your shirt pocket. A short plastic tube draws in air from the area near your face. A small pump, which may be attached to your belt or carried in a pocket, is attached to the sampler. The device is turned on at the beginning of your work day and turned off when you return to the bus depot. Carbon monoxide exposures are then read by connecting the sampler to an analyzer. All you have to do is wear the device for one complete working day.

Because tobacco smoking creates carbon monoxide and may cause misleading test results, it is very important that you be a non-smoker and that you avoid direct contact with tobacco smoke while you are wearing this device. You should also avoid direct contact with motor vehicle exhaust to the greatest extent possible.

SAI personnel will demonstrate use of the device and answer any questions.

Your cooperation and assistance are greatly appreciated.

If you are interested in being a volunteer, please contact ________________
____.

Form A-5

PERSONAL SAMPLER INFORMATION SHEET

Science Applications, Inc. (SAI) is conducting a study for the U.S. Environmental Protection Agency (EPA) to determine the incidence and causes of elevated levels of carbon monoxide in school buses, taxis, and police cars. As part of this study, we are seeking volunteers to wear a small device known as a personal sampler which measures carbon monoxide as you move about during one workday. This device poses no hazard to you, nor can it be used to track your movements. In order not to produce misleading test results, you must avoid direct contact with tobacco smoke and vehicle exhaust to the greatest extent possible. Our staff personnel will demonstrate the device and answer any of your questions. Your cooperation and assistance are greatly appreciated.

DATE

NAME OF FLEET

LOCATION OF DEPOT

Form A-6

SCIENCE APPLICATIONS, INC.

DATA SHEET

FLEET TESTING PERSONAL SAMPLER

PAGE OF

PREPARED BY:

(1) Serial Number Monitor	(2) Driver's Name	(3) Vehicle I.D.	(4) Initial Reading	(5) Start Time	(6) Stop Time	(7) Final Reading	(8) Net Reading (7)-(4)	(9) Average Reading (8)/ Time	(10) Driver's Location During Work Shift	(11) Average Ambient CO	(12) Average Vehicle Difference (9)-(11)

Form A-7

DATE

NAME OF FLEET

LOCATION OF DEPOT

SCIENCE APPLICATIONS, INC.
DATA SHEET

FLEET TESTING LOG STAGE 2

PAGE OF

PREPARED BY

VEHICLE ID NO.

CODE	TIME	DESCRIPTION

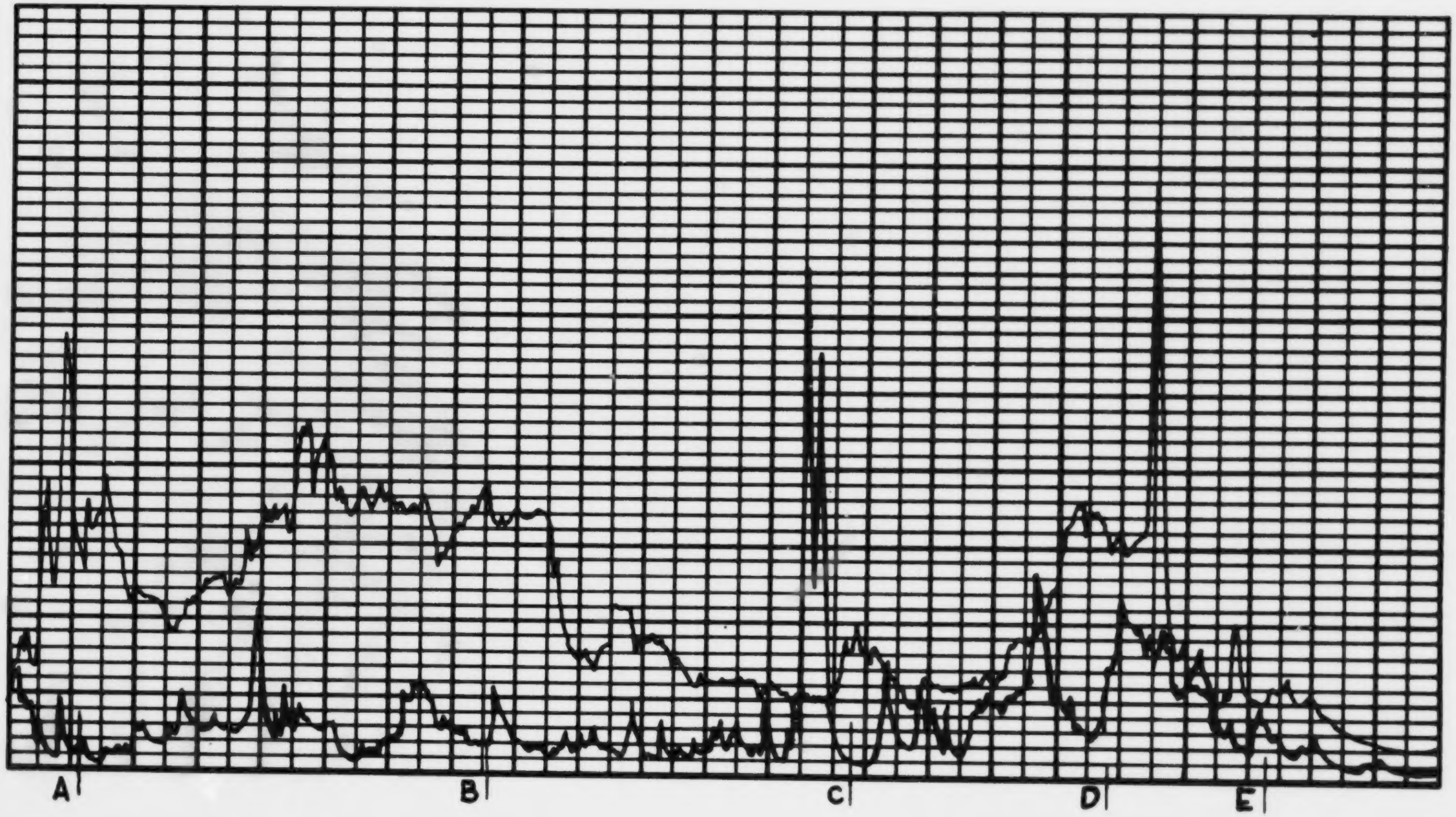


Figure A-1. Sample Continuous Analyzer Trace.

APPENDIX B

QUALITY ASSURANCE PROCEDURES

CALIBRATION PROCEDURES

Stain Tube Dosimeters

In order to estimate carbon monoxide concentrations rapidly from field data, it was desired to derive a mathematical relationship between stain length, time, and ambient concentration. At our request, Mine Safety Appliances Company (MSA) measured the glass tube dosimeter stain length resulting from several combinations of CO concentration and duration. Their results are shown in Table B-1. From these data it would appear at first that the CO concentration is related to stain length by a simple exponential formula:

$$C = ae^{mL} \tag{B-1}$$

where C is the concentration (ppm), L is the stain length (mm), and m is a constant. However, if one plots C versus L on semi-log graph paper, it becomes apparent that m is not a constant; rather, it depends upon L. Laboratory personnel at MSA concurred (McConnaughey, 1979).

According to classical theory, the solution of the equation governing diffusion of CO through the tubes would have the form:

$$C = k \operatorname{erfc} (L/\sqrt{t}) \tag{B-2}$$

where k is a constant and erfc is the complementary error function. Although it was inconvenient to use an equation of this form, the parameter $L/\sqrt{t}$ proved to be quite appropriate. Within discrete intervals of $L/\sqrt{t}$, an equation of the following form fit the data well:

$$C = a\, e^{m(L/\sqrt{t})} \tag{B-3}$$

where a and m are constants. Coefficients and standard errors of estimate, as determined by a least-squares log linear regression technique, are as follows:

Table B-1

CALIBRATION DATA FOR GLASS STAIN TUBE DOSIMETER

(Stain Length in Millimeters)

Ambient CO Concentration (ppm)	Exposure Time (hours) 4	6	8
0	0	0	0
8	1	1	1
20	1	1.5	2
35	2	2.5	3
60	3	3.5	4
90	4	4.5	5

Source: Mine Safety Appliances Company (McConnaughey, 1979).

Range of $L/\sqrt{t}$	General Range of CO (ppm)	a	m	Std. Error of Estimate
0.5 - 1.4	20 - 60	7.925	1.419	1.73
> 1.4	> 60	13.856	1.035	3.57

For values of $L/\sqrt{t} < 0.5$, a linear relationship was found to fit the data:

$$C = 0.040 + 20.80\ L/\sqrt{t} \qquad \text{(B-4)}$$

Std. Error = 0.564

It should be noted that for all of these relationships to be valid, the exposure time must exceed four hours.

Personal Samplers

Calibration--

The Ecolyzer® 9000 Carbon Monoxide dosimeters were calibrated by a procedure specified by the manufacturer (Energetics Science, Inc., 1978). In this procedure, the sampling pump is adjusted so that its flow rate with the dosimeter connected is between 100 and 120 ml/min. The dosimeter is then connected to the readout device, which contains an "edge meter" for instantaneous CO measurement. After the edge meter is zeroed, a sample bag is filled with calibration gas containing 40 to 80 ppm CO and is attached to the dosimeter sampling port. A span control is adjusted so that the meter reading corresponds to the known concentration of the calibration gas.

The dosimeter/pump combinations were calibrated at the start of the project; then as part of the once per month humidification procedure. A check on pump flow rate and the battery recharge level was done on a daily basis immediately prior to their issuances. In retrospect, considering the difficulty encountered in keeping units in service, it may be necessary to amend the approach to calibration and maintenance. Edge meter calibration is a relatively coarse procedure which does not effectively assure extended field life.

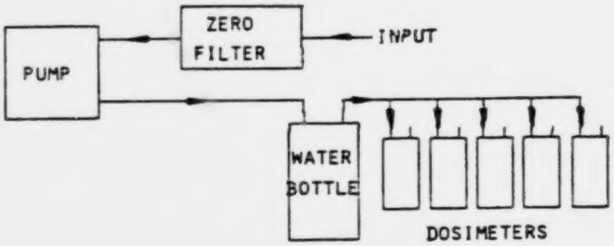
The recommendation is to retain sufficient dosimeters and perform extended exposures while other units are in the field. At weekly intervals, units should be interchanged. We recommend reserving at all times a set of dosimeters to be given 8- or 12- hour tests against a known standard while the other units are in the field. The reserve and field units would be exchanged weekly.

Humidification--

The manufacturer recommends humidifying the dosimeter sensor once per month or more often if the time for the edge meter reading to reach a steady state in the calibration procedure exceeds one minute. Figure B-1 shows a schematic of the humidification system. The water bottle is filled three-quarters full with water and tightly capped. The pump pushes air over the top of the water and into the output ports of the dosimeters. The procedure is run for about 48 hours.

Figure B-1

Schematic of Personal Sampler Humidification System


ZERO FILTER
INPUT
PUMP
WATER BOTTLE
DOSIMETERS

Continuous Analyzers

The Interscan® continuous CO analyzers are calibrated daily according to procedures specified by the manufacturer. All adjustments are made with the Soltec® recorder connected to the analyzers. After analyzers and recorders are warmed up, a zeroing knob on each analyzer is turned so that the analyzer's meter reads zero. The corresponding recorder pen is then adjusted so that it tracks the zero line on the strip chart. A Tedlar bag is filled with calibration gas of a known CO concentration(generally 30 to 60 ppm CO)and connected to the analyzer's inlet and the analyzer pump is turned on. A span adjustment screw on the analyzer is turned so that the pen position on the recorder chart corresponds to the calibration gas concentration.

QUALITY CONTROL TESTS

During the field measurements program, several tests were conducted to evaluate the precision of the glass stain tube dosimeters and the personal samplers, and to compare readings made simultaneously with two types of sampling devices. It was assumed throughout that the continuous analyzers had the best accuracy, approximately ± 2 percent of full scale(i.e. ± 1 or 2 ppm CO), according to the manufacturer; this accuracy was verified by SAI as part of two previous studies(Ziskind, et al., 1977; Ziskind, et al., 1978).

Theoretical Error in Glass Stain Tube Dosimeter Values

The main sources of error in measuring CO with the glass stain tube dosimeters were (1) calibration (2) judging the stain length (3) estimating the time of exposure. The standard error of estimate for the calibration was presented in Section B. If measurement parameters L and t are known exactly, the error due to variability of the calibration data would be approximately as follows:

Range of CO(ppm)	Calibration Error(ppm)
0-20	(Insufficient Data)
20-60	2.8
> 60	5.7

These errors are rather small. However, considerably greater errors could occur from incorrect interpretation of the stain length. Stain lengths are hard to read because the stain boundary is indistinct; in a practical situation, estimates are accurate to 0.5 mm at best. The theoretical total error due to errors in stain length reading and exposure time may be calculated by differentiating Equation B-3:

$$dC = \frac{\partial C}{\partial L}\,dL + \frac{\partial C}{\partial t}\,dt \qquad \text{(B-5)}$$

$$dC = amt^{-\frac{1}{2}}\,e^{mLt^{-\frac{1}{2}}}\left(dL - \frac{L}{2t}\,dt\right) \qquad \text{(B-6)}$$

Equation B-6 was calculated with those combinations of L and t which would yield desired total concentrations of C according to Equations B-3 and B-4. Figure B-2 shows the error bands for a given CO reading, with the assumptions that there is no error in the time estimate and that L is correct to the nearest 0.5 mm. The discontinuities at 20 and 60 ppm are due to the piecewise nature of the calibration formula. For a typical measured value of CO, 26 ppm, the actual value could be between 18 and 37, if both calibration and stain length reading errors are taken into account. Thus the glass stain tube dosimeters are useful only as a gross, first-cut tool for CO measurement.

Precision and Accuracy of Glass Stain Tube Dosimeters

In order to assess the variability among individual glass stain tube dosimeters, two tubes were collocated in each of 44 vehicles. All were read by the same person. In 35 of 44 cases, the tube readings were identical. There is no significant difference between the mean concentrations of the two samples of 44 tubes (t = 0.0305, d.f. = 86).

In another test of precision, 10 tubes were placed side by side on the front seat of a passenger automobile, which was driven around Denver for 7 hours and 20 minutes. The readings were as follows:

Tube No.	Stain Length (mm)	CO Conc. (ppm)
1	1.25	10
2	1.5	17
3	1.75	20
4	2.0	23
5	1.25	10
6	1.75	20
7	1.75	20
8	1.75	20
9	2.25	26
10	1.75	20

If one assumes that the readings and calibration were error free, then the 95-percent confidence interval for the mean would be 18 ± 3 ppm.

Finally, as a check on the accuracy of the stain tubes, a continuous analyzer was collocated with the ten tubes mentioned above and operated during the same time period. Although interior CO levels exceeded 20 ppm during the last half hour of the run, the time-weighted average concentration as measured by the continuous analyzer was only 4.6 ppm, considerably lower than the concentration measured by any of the 10 tubes. There was some question of whether this test obtained useful data since only a single continuous analyzer was used and uncertainty about recorder zeroing was expressed. In order to evaluate stain tube performance more methodically, another exposure was conducted.

A comparison between glass stain tubes and two Interscan continuous analyzers was carried out to evaluate the precision and the accuracy of the former. It should be noted, however, that stain tubes were used as a survey

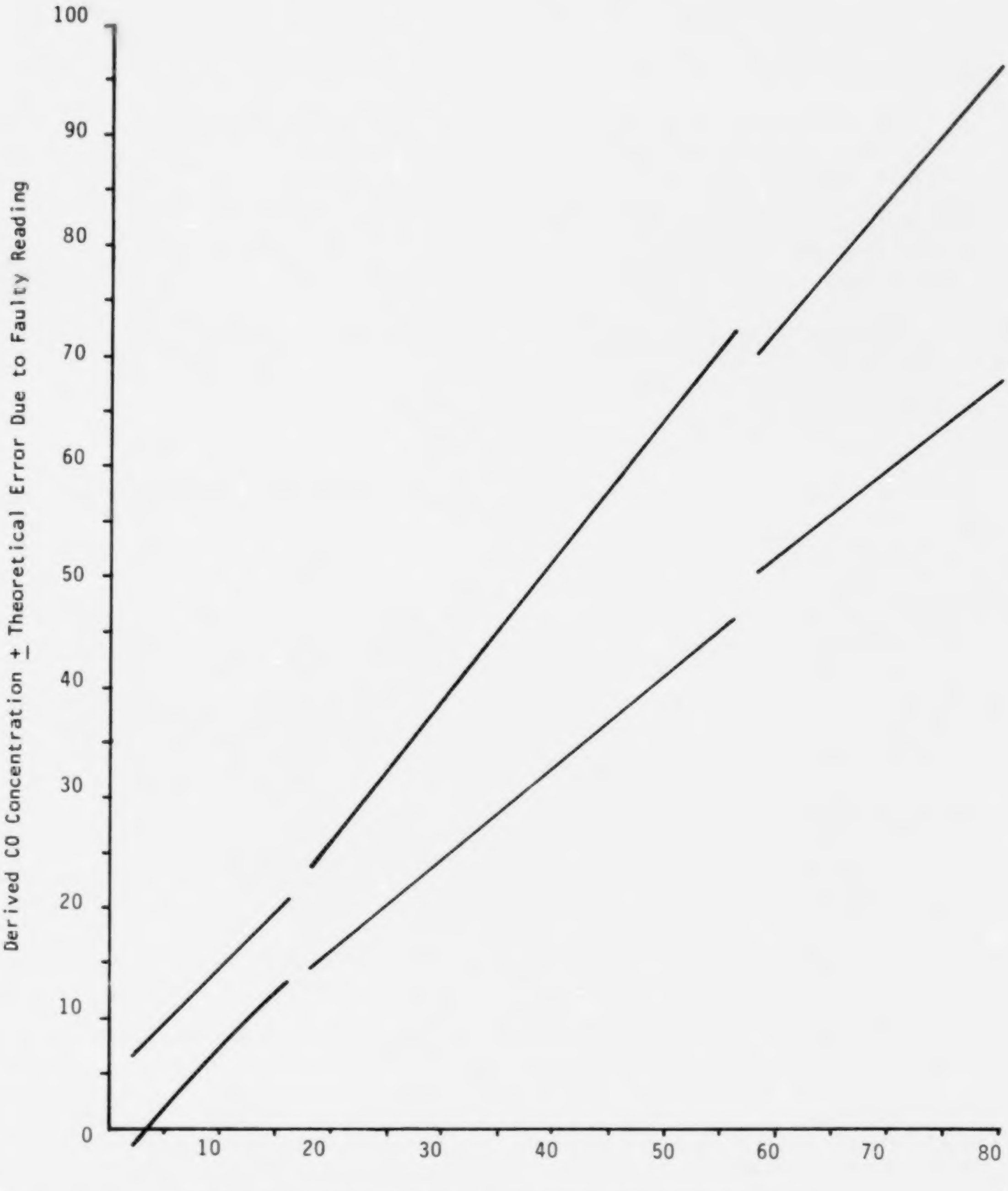


Figure B-2. Error Bands For Glass Stain Tube Dosimeter Reading
dL = 0.5 mm

tool in the study rather than to provide a "stand-alone" measure of CO exposure. They were principally used to develop a fleet aggregate average and secondarily to spot unusually elevated CO concentrations for further study.

The stain tubes were placed in a vehicle parked in a corner of the lowest level of a subterranean parking garage. Windows were only slightly open in order to damp out any transients in order to make the CO concentration relatively slow to change. Two Interscan® analyzers were zeroed and calibrated immediately before use with a span gas of 35 ppm. Thus, two independent recorded tracings of CO were obtained over the exposure period of slightly under 8 hours.

Nineteen glass tubes were exposed and the stain length estimated independently by two individuals. Differences in readings were reconciled by rereading or averaging. Readings and the corresponding concentrations are listed below:

Tube	Length (mm)	CO Level (ppm - average)
1	2	22
2	1	8
3	1.125	10
4	2	22
5	1.5	17
6	1.5	13
7	1.5	17
8		22
9	1	8
10	1	8
11	2	22
12	2	22
13	2.25	25
14	2	22
15	2	22
16	2	22
17	1.25	10
18	2.5	29
19	2.5	29

Mean = 18.63, $S = 6.841$; $S/\sqrt{n} = 1.569$; degrees of freedom = 18
95% Confidence Limit (15-22) ppm

The integration of the Interscan® analyzer traces showed an average concentration of 20-21 ppm. Therefore, statistically the average of the stain tubes closely agreed with the continuous analyzers. However, inspection of the stain tube data shows a fairly broad variation. It would appear that intercomparison of stain tube response across fleets is probably valid; however, it is unwise to quantitatively contrast single or even duplicated front values in a bus, since at most, three-four stain tubes had been used.

Accuracy of Personal Samplers

The numerous operating problems with the personal sampler dosimeters prompted a check on their accuracy. Two attempts were made to make simultaneous measurements with personal sampler units and continuous analyzers. In the first attempt, the readout device failed to function properly. In the second attempt, four dosimeters were collocated above the right windows of an AMC Concord rental car. A continuous analyzer was placed on the front seat and an intake tube connected to its sampling port was placed in the midst of the dosimeters. The car was driven through a wide variety of environments in and around downtown Boston. Both front windows were kept open throughout the two-hour run. Two of the personal sampler units appeared to be defective, indicating 0 and 120 ppm average CO concentration for the run. The results considered valid were:

	Mean CO 1st hour	Mean CO 2nd hour
Continuous Analyzer	16.6 ppm	9.6 ppm
Personal Sampler No. 1	11.8 ppm	7.4 ppm
Personal Sampler No. 2	17.4 ppm	9.9 ppm

These results indicate that personal samplers may be accurate to within about 5 ppm of the "true" continuous analyzer readings - provided that they work in the first place.

Independent EPA Calibration and Quality Assurance Procedures

Calibration gases, personal dosimeters, and continuous analyzers were evaluated by EPA immediately prior to shipment and utilization in this program. Methodology and results were summarized in this section.

Fourteen carbon monoxide gas cylinders used as span gases in the field test program were checked against two NBS standard reference materials by means of a Bendix® NDIR CO monitor. Specifically, the reference materials were:

NBS SRM 1677	9.74 ppm
NBS SRM 1679B	93.8 ppm

These provided end point references with which to calibrate the Bendix® NDIR. Each test gas cylinder was assayed by the NDIR and its concentration was recorded. Seven cylinders were independently assayed by a separate EPA laboratory, using the same procedure. Concentrations and percent difference are shown in the following chart.

Cylinder Serial Number	Assay A	Assay B	Percent Difference
10003	79.6		
10005	48.6		
10012	21.7	21.5	0.9
10021	8.0		
10022	49.0	48.5	1.0
10028	94.7		
10032	21.7		
10038	94.5	95.5	1.0
10040	8.0	8.15	1.9
10041	78.8	79.4	0.7
10043	36.0	36.1	0.3
10047	64.2	64.0	0.3
10048	36.0		

Personal dosimeters were humidified, zeroed, and spanned as described in the Calibration Section. Then several dosimeters were connected through a sampling manifold to a calibrated cylinder or through a dilution system and exposed to a known CO concentration over extended periods. Simultaneously, a precalibrated continuous analyzer (Interscan® CO Monitor or a Bendix® NDIR) sampled from the manifold and a strip chart recorder was connected to the output. The time-accumulated exposure was determined by integration of the recorder trace and compared with dosimeter values as shown below.

6-hour exposure with Interscan monitor value 345.7 ppm-hrs

Dosimeter Number	Reading	Percent Deviation
1407	334	- 3.4
1406	309	-10.6
1399	314	- 9.2
1409	315	- 9.9
1397	313	- 9.5
1416	312	- 9.7
1428	316	- 8.6
1419	309	-10.6
1402	325	- 6.0
1413	339	- 1.9

7-hour exposure with Bendix® NDIR value 275.1 ppm-hrs

Dosimeter Number	Reading	Percent Deviation
1519	292	+ 6.1
1520	397	+ 8.0
1517	300	+ 9.0
1516	299	+ 8.7
1518	273	- 8.0

6-and 17-hour exposures with Bendix® NDIR value 253.4 and 703 ppm hr respectively

Dosimeter Number	6-hr Reading	Percent Deviation	17-hr Reading	Percent Deviation
1530	257	+ 1.4	692	- 1.6
1537	258	+ 1.8	702	- 0.1
1532	256	+ 1.0	780	+11.0
1533	290	+14.4	811	+15.4
1534	252	- 0.6	684	- 2.7

In addition to these time exposure checks, the separate personal pump units were run with no dosimeter loads, and their flow rates were monitored. All pumps ran over 12 hours on a single battery charge and maintained close flow rate consistency as measured by a mass flow meter.

The Interscan® CO Monitors were checked out and calibrated by use of span gases. In addition to examining the instrument response as a function of CO concentration, the effects of relative humidity, temperature, and duration of battery life were measured. Temperature test values were 15.5, 20.5, and 25.5°C, while relative humidity was taken at 50 and 100%.

The monitors showed excellent linearity in their response as a function of CO concentration. Across each of the two concentration ranges of 0-50 and 0-100 ppm four span gas points were taken and lined up closely. Only on two units was any departure from linearity noted and that being the highest concentration only (65 and 80 ppm, respectively).

Response among instruments varied as a function of temperature and relative humidity. Results for three instruments are given below at 50% relative humidity over three temperatures.

	Response (ppm)		
Serial Number	15.5°C	20.5°C	25.5°C
22259	21.4	21.5	23.0
22278	18.6	21.5	23.7
22275	14.0	16.5	18.5

There is no significance to the absolute numbers but rather only to their variation with temperature. Deviation with temperature at 100% relative humidity is similar. Although these dependencies are significant, the program utilization of these instruments in the field testing is such as to mitigate these effects. Specifically, in the daily procedure using the continuous monitors, a pair of instruments was always used rather than one in order to simultaneously measure interior and exterior CO concentrations. Initially, the devices were zeroed and spanned at the home of the technician. They were then taken to the vehicle depot and rezeroed immediately prior to use and periodically thereafter. Therefore, both instruments would be subjected to the same conditions of temperature and relative humidity. Large differentials of interior over exterior concentrations were of principal interest. No attempt was made to apply corrections to the continuous analyzer readings, since values of relative humidity and temperature were not being recorded and insufficient data were available to confirm the repeatability of instrument performance with respect to these variables.

DELETION OF INVALID RESULTS

In three circumstances, CO concentration data obtained by glass stain tube dosimeters and personal samplers were considered invalid. First, because it was difficult to discern precisely the point of farthest advance of the stain in the glass tube dosimeters, technicians varied in their interpretations of the readings. On 19 April, 1979, all technicians were given a uniform procedure for reading the tubes and judging the position of the stain front. All readings made before 19 April were discarded.

In many cases, personal sampler readings were unreasonably high or low, as has been discussed in several places in the text of this report. In many of these cases, successive readings on the readout device would yield quite different results (e.g. 1102 and 1638 ppm-hrs). Readings were discarded where the technician indicated such difficulty; average CO concentrations were over 100 ppm (and there was no corroborating evidence of high levels); and where the technician indicated that the dosimeter failed to zero properly.

Finally, certain individual personal sampler pump/dosimeter combinations were determined to be defective after all data for a particular fleet were analyzed. A nonparametric statistical test showed in two instances that a total of three personal sampler units consistently gave low readings (<5 ppm average) under a wide variety of operating conditions and that there was an extremely low probability ($p< 0.001$) that the association of low readings with these instruments was due to chance. Readings for these units were discarded and the devices were sent to the manufacturer for repairs.

APPENDIX C - SUMMARY DATA WORKSHEETS
LEGEND FOR VEHICLE DATA SUMMARY

Make of Vehicle

Bus or Taxi

1	Ford (Ford Bluebird for B-1-A)
2	International Lodestar or Carpenter (Fleet B-1-A)(Superior B-3-B)
3	International Bluebird (Ward for B-1-A)
4	Dodge
5	Checker (cab) or Chevrolet CSE 635V (bus)
6	GMC SM502 (or Ford Superior for B-1-A)
7	GMC SE 63102 (or Suburban for B-1-A)
8	GMC TSE 635V
9	GMC SE 63162
10	GMC SM 58102
11	GMC 12 Thomas Diesel

Police Car

1	Plymouth Fury
2	Ford
3	Ford LTD
4	Ford Van
5	Chevrolet Nova
6	Pontiac

Tailpipe Location

Fleet B-6-A

1	Straight
2	Bent to left
3	Bent to right

All Other Fleets

1	Does not extend to end of body
2	Flush with end of body
3	Extends beyond end of body
4	Dual pipes

Exhaust System Condition

o	Nofaults
1	Tailpipe dented or crumpled
2	Tailpipe rusted
3	Hole(s) in tailpipe
4	Tailpipe bent
5	Faulty connection(s)
6	Tailpipe loose
7	Crack(s) in tailpipe
8	Tailpipe partly broken off

Intrusion Points or Evidence

Cabs and Police Cars

1	Poor door seals
2	Oily film on back seat
3	Soot in trunk or on back seat
7	Poor trunk seal or holes in trunk floor
8	Holes in back deck or body

Buses Only

1	Poor front door seals
2	Poor rear door seals
3	Poor window seals or malfunctioning windows in front
4	Poor window seals or malfunctioning windows in rear
8	Holes in body

All Vehicles

5	Holes in floorboard in front
6	Holes in floorboard in rear
9	Other

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-1-A   CITY: ______   TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage IN 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
3	5	9	77	25	1.0	2	0		↑		0[b]		4	26														
4	2	48	75	51	1.4	↓	1				0[c]	3	4	26														
5	2	48	76	50	10.0	↓	1				6		4	26														
6	1	60	70	114	4.0	3	0				0	3	4	26														
7	2	48	76	56	6.0	2	↓				0	9	4	27														
8	5	9	77	23	3.0	↓	↓				0	0	4	26														
9	1	60	70	124	4.0	↓	↓				8	17	4	27														
10	2	66	75	46	6.0	↓	↓				7	7	↓	26														
11	6	66	72	102	2.0	↓	↓				0[d]	0	↓	↓														
13	3	66	74	73	2.5	↓	↓				7	3	↓	27														
16	1	60	70	107	7.0	1	↓				3	0	↓	↓														
17	6	66	72	94	4.0	3	↓				7	7	↓	↓														
18	6	↓	72	100	5.5	3	↓				7[a]	7	↓	26														
19	2	↓	75	74	4.0	2	↓				10	3	↓	27														
20	2	↓	75	63	2.5	↓	↓		NOT OBSERVED		7	25	↓	27	0-1 PPM													
21	5	9	77	18	8.0	↓	↓				4		↓	26														
22	1	12	72	31	1.0	1	2				10[e]		↓	↓														
24	1	60	70	113	2.6	2	0				0	7	↓	↓														
25	6	66	72	95	5.0	2	0				0		↓	↓														
26	1	60	70	110	10.0	↓	↓				0	3	↓	↓														
27	2	48	75	54	4.0	↓	↓				3		↓	↓														
28	5	9		33	3.0	↓	↓				7		↓	27														
30	2	48		74	4.0	1	↓				0		↓	26														
31	6	66	72	88	7.5	3	↓				3	0	↓	↓														
32	6	↓	72	86	5.8	2	↓				3		↓	↓														
34	2	↓	75	42	1.8	↓	↓				0		↓	↓														
35	3	↓	74	56	6.0	↓	1				7		↓	↓														
36	1	73	73	73	8.0	↓	0				10	7	↓	↓														
37	2	66	74	62	2.0	2	↓				3	0	↓	27														
38	2	66	74	85	5.0	2	↓		↓		0		↓	26														

[a] Second measurement: 7 and 19 ppm on 4-27-79

[b] Second measurement: 3 ppm on 4-27-79

[c] Second measurement: 3 ppm on 4-27-79

[d] Second measurement: 0 ppm on 4-27-79

[e] Second measurement: 0 ppm on 4-27-79

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-1-A

CITY: ____

TYPE OF VEHICLE.: BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
39	2	66	74	81	11.0	2	0	NOT OBSERVED			0	19	4	26	0-1 PPM													
40	2	66	74	68	8.0	↓	↓	↓			7	10		27	↓													
42	1	60	70	128	8.0	↓	↓	↓			0			26	↓													
44	3	66	74	72	11.6	↓	↓	↓			0	3		27	↓													
45	3	↓	↓	60	9.5	↓	↓	↓			3			26	↓													
46	↓	↓	↓	62	1.5	↓	1	↓			0[a]			↓	↓													
51	↓	↓	↓	72	12.0	↓	1	↓			4			↓	↓													
54	1	60	70	120	3.0	↓	9	↓			10	0		↓	↓													
58	6	66	72	84	4.0	↓	0	↓			0	7		27	↓													
59	6	↓	72	97	6.5	↓	0	↓			0			26	↓													
60	2	↓	74	74	3.6	↓	9	↓			3	19		↓	↓													
61	↓	↓	75	42	2.1	↓	0	↓			7			↓	↓													
63	↓	↓	↓	39	9.0	↓	↓	↓			3	10		↓	↓													
65	↓	↓	↓	56	5.5	↓	↓	↓			7			27	↓													
66	↓	48	76	55	5.0	↓	↓	↓			0			26	↓													
67	↓	68	75	63	2.6	1	↓	↓			7	7		↓	↓													
68	↓	66	76	35	4.7	3	↓	↓			6	6		↓	↓													
69	↓	66	75	51	11.0	3	↓	↓			7	7		↓	↓													
70	↓	16	75	51	11.0	2	↓	↓			0			↓	↓													
71	↓	66	76	36	6.0	2	↓	↓			3			↓	↓													
72	1	30	75	73	3.0	3	↓	↓			7			↓	↓													
77	2	66	74	55	5.0	2	↓	↓			7	32		27	↓													
79	1	30	75	70	9.5	↓	↓	↓			0	3		26	↓													
80	2	16	↓	44	3.5	↓	↓	↓			3	7		27	↓													
81	5	9	↓	63	2.8	↓	↓	↓			3			27	↓													
83	7	9	76	43	2.5	↓	↓	↓			0			26	↓													
84	7	9	76	25	5.4	3	↓	↓			4			↓	↓													
86	3	65	77	24	3.8	2	↓	↓			0	6		↓	↓													
87	2	66	76	47	7.0	↓	↓	↓			10			27	↓													
88	3	65	77	33	2.5	↓	↓	↓			6	19		27	↓													

[a] Second measurement: 0 ppm on 4-27-79

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-1-A CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
89	2	66	76	44	3.8	2	1		NOT OBSERVED		0	0	4	26	0-1 PPM													
90	3	65	77	22	1.8	↓	0				7	0		↓														
91	3	65	77	16	11.0	↓	↓				0	7		↓														
94	2	66	76	50	9.5	↓	↓				0			↓														
95	3	65	77	18	7.5	1	1				7	3		↓														
97	1	60	69	115	15.0	2	0				7	0		27														
98	↓	↓	↓	135	10.0	↓	0				0	0		26														
99	↓	↓	↓	121	10.0	↓	1				7	0		27														
100	↓	↓	↓	127	12.0	3	0				0	0		26														
101	↓	↓	↓	114	4.0	2	↓				0			26														
102	↓	48	↓	169	9.0	↓	↓				0	0		27														
103	↓	48	↓	152	12.0	↓	1				0[a]	0		26														
105	↓	60	70	113	12.5	↓	0				0[b]	0		↓														
106	↓	↓	↓	127	7.0	↓	↓				0	0		↓														
107	↓	↓	↓	113	12.5	↓	↓				3	0		27														
108	↓	↓	↓	140	10.0	1	↓				3	7		27														
109	↓	30	↓	159	9.0	2	↓				0			26														
110	↓	36	↓	146	6.0	↓	↓				9			↓														
112	↓	60	71	84	4.0	↓	↓				0			↓														
113	↓	↓	↓	69	9.0	↓	↓				6	6		27														
114	↓	↓	↓	82	7.0	1	↓				0[c]	7		26														
115	↓	↓	↓	93	8.0	↓	↓				0			↓														
116	↓	↓	↓	99	9.0	↓	1				0			↓														
117	↓	↓	↓	96	6.0	2	0				0			↓														
118	↓	↓	↓	99	4.0	1	0				d			↓														
119	↓	↓	↓	83	3.0	1	1				3	3		26														
121	7	9	72	90	9.8	2	0				7	10		↓														
123	1	12	↓	123	3.0	1	0				10			↓														
127	6	66	↓	88	7.5	1	↓				0	7		↓														
128	2	18	75	65	5.0	2	↓				0			↓														

a Second measurement: 7 and 0 ppm on 4-27-79
b Second measurement: 0 ppm on 4-27-79
c Second measurement: 0 ppm on 4-27-79
d Tube defective

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-I-A

CITY:

TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
129	2	18	75	55	4.5	1	0	not ob-			7	6	4	26	0-1 PPM													
133	3	16	78	4	2.0	3	0	served			6		4	26														

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-2-A CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts A B C	Stain Tube CO F	Stain Tube CO R	Stain Tube Date Mo	Stain Tube Date Day	Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date Mo	Personal Sampler Date Day	Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm) Interior Ave	Interior Loc	Interior Peak	Interior Loc	Exterior Ave.	Exterior Loc	Exterior Peak	Exterior Loc	Type of Route
1069	2	66	73	79.6	1.8	1	0	3,4	0	3	4	9	1													
1071	2			81.5	3.5	3	0	5	7		4	9	1													
1078			74	80	2	3	0	3,4,5	5	28	4	10	3													
1079				62.8	3.2	3		3,4,5	30		4	9	1	4.9	5	10	1.1									
1083				68.2	8.1	3	0	0	6		↓		↓													
1084			73	59.6	11.1	3	0	3,4	53		↓		↓													
1085			74	80.3	8.3	1	0	0	21		↓		↓	3.6	5	9	1.7									
1086				84.1	12.1	2	0	0	9		↓		↓													
1087				68	8	2	0	0	23		↓		↓	17.2[a]	5	9	1.7									
1088				62.7	2.7	2	0	0	20		4	10	3													
1089				66.4	6.4	3	0	0	4	16	4	9	1													
1090				71.3	11.3	3	0	1	7		4	10	3													
1091				49.1	1.1	2	0	3,4	23		4	9	1													
1093	3		75	5.8		3	0	0	4		↓		↓	0.4	5	10	1.1									
1095	↓			72.4	12.4	3	0	3,4,5	20		↓		↓	9.1	5	9	1.7									
1096	↓			60.2	12.2	3	0	0	7		↓		↓													
1098	↓			63.8							↓		↓	3.0	5	10	1.1									
1099	↓			58.9	10.9	3	0	3,4	10		↓		↓													
1100	3		74	74.4	12.4	3	0	0	20		↓		↓													
1103			75	63.2	11.2	3	0	5,4	20		↓		↓													
1106				61	13	3	0	0	21		↓		↓	29.0	5	9	1.7									
1108				60.2	12.2	2	0	0	20		↓		↓													
1112				80.6	12.6	1	0	1	10		↓		↓													
1115				64.6	1.6	3	0	0	16		↓		↓													
1130				46.8	10.8	3	0	0	7		↓		↓													
1134	1	22	76	37.9	1.9	2	0	2	7		↓		↓	33.1	5	11	0.8									
1148	1	66	75	54.5	6.5	2	0	0	20		4	10	3	3.0	5	11	0.8									
1155	1	22	77	22.	10	2	0	3	16	7	4	9	1													
1127									19	10	↓		↓													
1123									4		↓		↓	0.9	5	10	1.1									
1070									10																	

a Second Day 5/10 0.2 ppm

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-2-A

CITY: ______

TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
1095																												
1148																				17^{a}		> 50		5		> 50		5/3/79
1100																				8		> 50		9		> 50		5/4/79
1084																				5		31		10		> 50		5/1/79
1084																				6^{b}		> 50		8		> 50		4/30/79 pm
1074																				15		37		11		> 50		4/30/79 am
1129																29.7	5	9	1.7									
1110																25.3	5	10	1.1									
1128																35.6	5	10	1.1									
1105																7.7	5	11	0.8									
																84	5	11	0.6									

a Inside levels exceeded outside levels during much of run

b Fixed station readings< 2ppm

c Fixed station readings 1.12 to 1.37ppm

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-2-B CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
1064				NOT INSPECTED																								
1065																37.1	5	14	0.8									
1067	2		75	77	5138	2	0		0		7	32	4	23	0.5	0.4	5	15	0.9									
1068				NOT INSPECTED																								
1097	2		75	57	8960	3	0		0		20	10				3.0	5	15	1.1									
1102	2			60	270	3	0				0	20				2.7	5	15	1.0									
1107	3			53	4668	1	5				20	20																
1109	3			62	1873	2	0				53	33				6.5	5	14	0.8									
1111	3			64	4446	2	5				32	7				24.3	5	14	0.8									
1114	3			68	7802	1	0				20	0				2.8	5	15	1.1									
1117	1			48	11773	2	0				10	10																
1119				42	5176	2	0				7	20				1.6	5	14	0.8									
1124				46	X[b]	2	5				7	7				0.9	5	15	0.8					NOT				
1126				47	11133	2	0				20	32				36.0	5	14	0.8					MEASURED				
1131				47	X	3	0				30	7																
1132				44	X	2	0				32	20																
1137				44	X	2	0				20	20				29.2	5	14	0.8									
1139				37	X	2	2				20	20				3.1	5	14	0.8									
1141				41	X	3	0				7	0																
1142				NOT INSPECTED																								
1143	1		76	46	X	3	2				20	49				3.5	5	14	0.8									
1144				51	5565	2	5				20	7																
1146				40	4000	1	2				20	20				3.1	5	15	1.0									
1149				41	X	3	2				32	20																
1150				42	X	2	0				3	7																
1153				37	1345	3	0				20	20																
1154				37	X	2	0				20	7				61.0	5	15	0.8									

a One station
b X = No data

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-A CITY: ______ TYPE OF VEHICLE : ______

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
1	2	25	78	12.6	5.8	1	0		0		10		4	17	3													
5	1	28	74	69.1	7.4	3	↓		↓		10	10	4	17*	3													
6	2	24	76	46.1	9.0	3	↓		↓		14		4	18	2													
8	2	16	78	13	5	3	↓		↓		10		4	17	3													
9	2	48	78	10.4		2	↓		↓		10		4	16	2.5													
11	2	48	78	9.9	3.7	3	↓		↓		14	20	4	16	2.5													
12	2	48	78	12.2	5.5	2	↓		↓		10	10	4	16	2.5													
15	2	48	78	6.3		2	↓		↓		14		4	16	2.5													
19	1	28	74	82.5	4.2	3	↓		↓		24	37	4	18	2													
20	1	72	74	75.4	2.1	3	↓		↓		10	24	4	18	2													
22	2	55	76	35.	8.3	2	↓		↓		20		4	18	2													
24	2	55	76	47.5	5.3	2	↓		↓		14		4	18	2													
28	2	55	76	35.8	4.2	2	↓		↓		39	39	4	17	3					10		25		5		750		5/16/79
34	11	18	78	10.3			↓		↓		37	24	4	18	2													
35	11	16	78	6.3		2	↓		↓		14	37	4	16	2.5													
36	11	16	78	6.6		1	↓		↓																			
48	1	36	67	96.4		2	↓		↓		10	24	4	16	2.5													
49	1	42	67	190.	10	2	↓		↓		14		4	18	2													
51	1	36	67	86.1		3	↓		↓		10	14	4	16	2.5													
67	1	78	74	81	0	3	↓		↓		20	20	4	16	2.5													
75	1	78	74	99.6	0.4	3	↓		↓		20	10	4	18	2													
76	1	60	70	134		3	↓		↓		37	24	4	18	2					8		23		3		41		5/9/79
81	1	78	74	108	6.0	4.3.	↓		↓		14		4	16	2.5													
83	1	78	74	92.9	4.7	4.3	↓		↓		10	79	4	17	3													
84	1	60	70	145	3.0	3	2		↓		14	10	4	18	2													
89	1	60	70	139	0.3	1	0		↓		10		4	18	2													
92	1	60	70	141	11.5	3	↓		↓		10	10	4	18	2													
93	1	60	70	138	19	3	↓		↓		39	39	4	17	3					8		45		8		750		5/15/79 a
94	11	60	69	150	9	2	↓		↓		10	10	4	18	2													
300	2	65	78	17.4	3	1	↓		↓		10		4	18	2													

a Inside exceeds outside much of the time during the run

* Additional readings on 4/18: 20 24

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-A

CITY:

TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
301	11	65	78	8.1		1	0	0			10		4	18	2													
302	11	66	78	3.3		3	0				14		4	17	3													
331	1	60	70	130	35	2	0				14	20	4	17	3													
334	1	60	70	146		3	0				14	10	4	17	3													
336	11	60	70	113	10	2	0																					
343	1	60	72	133.5	1.5	3	0				14	20	4	18	2	14.0	6	6	1.1									
345	1	60	72	117	21.3	1	0				14	0				43.0	6	6	1.0									
347	1	60	72	115	10	2	0				20		4	18	2													
354	1	60	72	106	7	1	0				10	14	4	18	2													
357	1	60	74	134	49	2	0				10	10	4	17	3													
361	1	78	74	92	0.6	2,4	0																					
363	1	78	75	72	4.1	3,4	0				10		4	17	3													
364	3	78	75	72.5	13.6	3,4	0				10	14	4	18	2													
369	1	54	75	68.3	3.0	3,4	0				20		4	18	2	21.3	6	5	3.1									
370	1	54	75	63.4	13.4	2	0				14		4	18	2													
375	1	66	75	78.0	4.0	2	0				20	33	4	17	3													
382	3	55	76	58.8	13.0	2	0				10		4	18	2													
383	3	55	76	50.5	0.8	2	0				14	10	4	17	3													
387	3	55	76	47.4	9.0	2	0				10		4	18	2													
388	3	55	76	44.3	1.1	3	0				10	14	4	18	2													
389	3	55	76	54.6	0.5	2	0				24		4	18	2													
391	3	55	76	52.5	10.0	2	0				10		4	17	3													
392	3	55	76	42.3	3.0	1	0				10		4	17	3													
397	3	55	76	42.3	0.6	2	0				20		4	18	2													
400	3	55	76	41.3	1.3	2	0																					
403	3	66	76	48.0	2.8	2	0				10		4	18	2													
408	3	66	76	34.2	0.0	2	0				24	39	4	17	3													
409	3	66	76	42.4	3.1	3	0				14	10	4	17	3													
418	3	66	76	37.4	8.1	2	0				14		4	17	3													
421	3	66	76	39.1	0.0	2	0				10		4	17	3													

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-A CITY: ______ TYPE OF VEHICLE.: BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
423	3	66	76	51.6	1.3	2	0		0		14	10	4	16	2.5													
428	3	66	76	45.4	0	2	0				14	20	4	18	2													
438	3	66	76	46.4	4.3	2	0				10		4	16	2.5													
445	3	66	76	47.3	3.6	2	0				20	10	4	18	2													
446	3	66	76	51.5		1	0				10		4	16	2.5													
453	3	66	76	39.0	1.5	3	0				10		4	17	3													
456	3	66	76	48.4	1.9	2	2				10	10	4	18	2													
457	3	66	76	44.3	0.1	2	0				24	37	4	18	2					10		>50		12		44.>50		5/14/79
459	3	66	76	47.6	5.1	2	0				10	20	4	18	2													
462	3	66	76	44.3	2.0	2	0				10		4	17	3													
463	3	66	76	34.4	1.2	2	0				10		4	17	3	9.6	6	5	1.9									
465	3	66	76	44.4	6.7	2	0				10	20	4	17	3	20.5	6	6	3.9									
467	3	66	76	47.9	14	2	0				10	33	4	17	3													
475	3	66	76	44.5	16	2	0				14		4	18	2	2.1	6	5	2.1									
480				49.5	1.2	3	0				10	37	4	18	2					10		>50[a]		20		>50		5/15
482				47.8	0.2	2	0				10	24	4	18	2													
483				46.6	11.8	2	0				10		4	17	3													
484				40.7	2.8	2	0				20		4	18	2													
505			74	79.1	1.9	2	0				24																	
510			74	71.4	0.8	2	0				14	20	4	17	3													
527			74	64.8	2.7	3	0				10	39	4	16	2.5					5		34		8		>50		5/4/
531			74	65.5	3.1	2	0				20		4	17	3													
533				63.8		3	0				10		4	18	2													
537				56.8	2.4	2	2				10	10	4	18	2													
539				58.1	6.6	2	0																					
541				80.6	12.3	2	0																					
547				81.4	2.0	2	0				14	39	4	17	3													
548				79.5	1.8	3	0,1				14	20	4	16	2.5													
549				70.5	10.7	2	0				10	(20)*	4	17	3													
550				71.4	9.6	2	1		↓		10		4	18	2													

a The outside level stayed above 50ppm much of the time

* Additional reading on 4/18

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-A CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
551	3	66	74	66.3	4.3	2	0		0		14		4	17	3													
554	3			72.1	8.6	2	0				14	10	4	16	2.5													
555				71.7	2.6	3	0				14	10	4	16	2.5	5.1	6	5	0.8									
556				76	8.3	2	0				10	10	4	17	3													
558				71.9	3.8	2	0				10		4	18*	2													
560				76.7	3.0	3	0.1				14		4	16	2.5													
562				71.8	4.9	2	0.1				14	(14	4	16	2.5													
566				60	4.5	2	0.1																					
567				63.9	1.7	2	0				37	37	4	16	2.5					12		41		8		> 50		5/4/79
702	3	78	77	98.1		3	0				10	14	4	17	3													
703				33	4.0	3	0				10	14	4	16	2.5													
707				37.9	0.2	2	0.2				10	4	4	16	2.5													
726											10		4	18	2													

* Additional readings on 4/18: (10)

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-B

CITY:

TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
18	1	78	74	91.7	13.4	2	0,4		0		20		4	23	3													
21	3	55	76	43.4	12.3	2	0				6	13	4	18	^{b} 2													
23	3	55	76	50.2	2.7	2	0																					
25				46.5	4.4	2	0				6		4	17	4													
26				61.7	4.9	2	0				6		4	17	4													
27				39	13.8	2	0				8		4	18	2													
31	1	54	70	158	6	3	0				6		4	17	4													
32				152.7	10.8	3	0																					
33				152.9	0	1	0				6		4	18	2													
46		66		145	3.4	3	1				20	10	4	23	3													
47				130	0	3	0				19	6	4	18	2													
50				155	8	2	0^{a}				6		4	17	4													
53				172.5	7	2	0^{a}				6		4	17	4													
54				131	0.5	2	0^{a}				6^{c}		4	18	2													
59		60		112	13	2	$0,1^{a}$				6		4	17	4													
60	3	78	74	39.6	9.3	3,4	0																					
62	3	78	74	159	0.5	3	1^{a}																					
64	11	66	74	64.5	7.6	3	1^{a}																					
65	1	60	70	149	16	3	0				6		4	17	4													
66	3	78	74	107.2	12.1	3,4	0				6	6	4	18	2													
68	3			80.5	8.2	2,4	0^{a}				6	8	4	18	2													
70				83.7	4.4	2,4	5,1				7		4	23	3													
71				83.7	4.4	2,4	0^{a}																					
72				99.7	15.1	3,4	4				6		4	17	4													
73				92.4	16.1	2,4	0				8	6	4	17	4													
74				89.8	6.6	3,4	0^{a}				6	6	4	18	2	6.2	5	30	2.3									
77	1	54	70	143.5	1.3	2	0				7		4	23	3													
79	3	78	74	77.2		3,4	0^{a}				20		4	23	3													
85	3	60	70	138.3	1.1	2	0^{a}				6	6	4	18	2													
86	11	54	68	196.8	13.8	2	0																					

a Carbon Coating

b read second day 6ppm 4/17

c also read 4/23 3ppm

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-B CITY: ____ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
87	1	60	70	158.6	12.3	2	1		0		13	6	4	18	2													
95	1	60	70	163.6	3.8	2	0[a]		↓		6		4	17	4													
97	3	78	69	177.3	0.4	2	1		↓		6	6	4	18	2													
98	3	78	69	148.7	2.7	2	1[a]		↓		19	7	4	23	3													
304	11	65	78	6.1	6.1	3	0		↓							12.5	6	4	3.5									
305	11	↓	↓	5.3	5.3	1	0		↓		7	7	4	23	3													
306		↓	↓	6.4	6.4	2	0		↓		6	6	4	18	2													
314	1	78	74	99		2,4	8		↓																			
315		↓	↓	84.5	1.4	2,4	0		↓		10	20	4	23	3													
330	4	60	70	147.8	1.6	2	0		↓		6	6	4	18	2													
332	1	60	70	140	2.2	2	0		↓		7		4	17	4													
337	11	60	70	133	17	3	0[a]		↓		13	6	4	17	4													
338	11	↓	↓	97.6	0	1	0		↓																			
342	1	60	72	121.3	9.5	2	0[a]		↓		19		4	23	3													
344	1	↓	↓	124.8	1.8	3	1		↓		7	20	4	23	3													
346	1	↓	↓	118.5	9	2	0[a]		↓		6	6	4	18	2													
348	1	↓	↓	111	5	2	0		↓		13	6	4	18	2													
349	↓	↓	↓	118.5	9	2	0		↓																			
350	↓	↓	↓	124	2.5	3	0		↓																			
351	↓	↓	↓	131	17	1	0[a]		↓		13	6	4	18	2													
352	↓	↓	↓	119	1.5	3	0		↓		20	6	4	18	2													
353	↓	↓	↓	70	0	3	0		↓		6		4	23	3													
355	↓	↓	↓	113.7	5.7	1	0		↓		6	6	4	17	4	14.9	5	30	0.3									
356	↓	↓	↓	99.3	9.9	1	0		↓		6		4	17	4	22.3	5	30	2.1									
358	3	66	74	70	6.5	2	0		2		19		4	17	4	15.7	5	30	2.0									
362	↓	↓	↓	80	3.2	2,4	0		0		20	20	4	23	3													
365	1	78	75	74.5	14.2	3,4	0		↓		6	6	4	17	4													
368	11	54	74	66.3	0.5	2	0		↓		7		4	23	3													
372	11	↓	↓	57.8	3.6	1	0[a]		↓		13	6	4	17	4													
374	11	60	75	57.3	2.2	1	1		↓		13	6	4	17	4													

a Exhaust coated with black soot

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-B CITY: TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
376	3	55	76	66.7	2.4	2	1		0		13		4	18	2													
377	↓	↓	↓	59.1	18.5	3	0		↓		6	6	4	18	2													
379	↓	↓	↓	56.2	4.2	2	0		↓		19		4	23	3													
380	↓	↓	↓	58.4	8.5	3	0		↓		6		4	23	3													
385	↓	↓	↓	56.7	7.7	3	1		↓		13	6	4	18	2													
386	↓	↓	↓	68.7	7.8	1	0		↓		18		4	23	3													
390	↓	↓	↓	61.4	0.8	2	0^a		↓		6		4	23	3													
393	↓	↓	↓	55.5	3.2	3	0		↓		6		4	18	2													
394	↓	↓	↓	53.8	6.5	2	7		↓		7		4	23	3													
398	↓	↓	↓	35.1	15.4	2	0		↓		6		4	23	↓													
399	↓	↓	↓	46.1	6.2	3	0		↓		6		4	23	↓													
402	2	66	76	40.4	0	1	0		↓		6		4	23	↓													
405	↓	↓	↓	47.5	16.2	2	0		↓		10		4	23	↓													
406	↓	↓	↓	33.6	0.4	2	0		↓		7		4	23	↓													
407	↓	↓	↓	45.2	2.7	2	1		↓		6		4	18	2													
410	↓	↓	↓	38.5	5.0	2	0		↓		10		4	23	3													
412	↓	↓	↓	47.0	3.4	1	0		↓						↓													
413	↓	↓	↓	44.6	4.1	2	0		↓		20		4	23	↓													
414	↓	↓	↓	41.2	0.9	2	0		↓		25		4	23	↓													
415	↓	↓	↓	34.9	12.2	2	0		↓		20		4	23	↓													
416	↓	↓	↓	32.9	11.4	2	0^a		↓						↓													
417	↓	↓	↓	31.6	0.9	2	0		↓		7	10	4	23	↓													
420	↓	↓	↓	36.4	0.3	2	0		↓		0	17	4	23	↓													
422	↓	↓	↓	33.3	3.6	2	0		↓		10		4	23	↓													
424	↓	↓	↓	45.2	10.8	2	0		↓		25		4	23	↓													
426	↓	↓	↓	52.8	2.5	1	0		↓		19	19	4	23	↓													
427	↓	↓	↓	47.8	6.7	2	0		↓		6		4	23	↓													
429	↓	↓	↓	31.9	8.8	2	0^a		↓		6		4	23	↓													
430	↓	↓	↓	28.6	2.4	1	0		↓		6		4	23	↓													
431	↓	↓	↓	31.4	8.1	3	0		↓		6	6	4	23	↓													

a Exhaust coated with black soot

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-B CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm) Interior				Exterior				Type of Route
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
432	2	66	76	33.7	4.0	2	0		0		6	6	4	17	4													
433				56.6	15.2	2	0				20		4	23	3													
434				46.1	0.3	2	0				8	6	4	17	4													
435				43.2	1.5	2	0		↓		6		4	17	4													
436				38.4	10.3	2	0[a]		5																			
437				34.4	2.8	2	0		0																			
439				36.0	15	2	0				19		4	18	2													
440				33.1	0.7	2	0				6	6	4	18[b]	2													
442				42.2	4.5	2	0				13		4	18	2													
448				45.2	15.3	1	0		↓		6		4	17	4													
449				44.1	5.6	1	0		5		6	19	4	17	4													
450				46.2	8.5	2	0		0		6	6	4	18	2	15.2	5	30	3.1									
452				47.6	3.9	2	1		5		6		4	18	2													
454				46.4	0.6	2	0		0		6		4	18	2	19.9	5	30	1.9									
460				33.1	1.9	3	0				6		4	17	4													
464				40.7	10.8	2	0				20		4	23	3													
466				54.0	3.2	2	0				6		4	18	2													
469				46.1	14.0	1	0				13	6	4	17	4	7.4	6	4	3.5									
470				36.9	0.1	3	1																					
471				39.7	10.2	1	0				6		4	17	4													
472				42.1	2.7	2	0				20		4	23	3													
474				39.1	11.2	2	0				7		4	23	3													
476				41.7	0.1	2	0[a]				6		4	17	4													
477				35.8	0.1	2	0[a]				6		4	17														
479				57.9	4.1	2	0[a]				6		4	17		30.8	5	30	1.9									
481			79	44.3	6.5	1	0		↓		6		4	17	↓													
486			76	32.2	2.9	2	0		5																			
488				39.9	6.3	3	0		0		6		4	18	2													
489				41.0	2.6						6		4	17	4													
490	↓	↓	↓	41.8	2.1	2	0		↓		7	20	4	23	3													

[a] Exhaust coated with black soot

[b] Second day's measurements 6F, 6R 4/17

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-B CITY: ____ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
500	3	66	74	53.9	1.6	1	0		0		7	0	4	23	3													
502	↓	↓	↓	71.8	8.1	1	1[a]		↓		6	6	4	17	4													
503	↓	↓	↓	68.9	1.7	2	1		↓		6		4	18	2													
504	↓	↓	↓	69.4	14.4	3	0		↓		13	6	4	18	2													
506	↓	↓	↓	75.5	2.0	2	4,1,2		↓																			
507	↓	↓	↓	75.8	4.0	2	0[a]		↓		13		4	18	2													
508	↓	↓	↓	67.1	7.5	2	1[a]		↓		6		4	17	4													
509	↓	↓	↓	65.8	1.0	2	1[a]		5		0		4	18	2	35.3	5	30	0.7									
511	↓	↓	↓	75	5.4	3	1		0		6	6	4	17	4													
513	↓	↓	↓	68	7.2	2	0		↓		25		4	23	3													
514	↓	↓	↓	67.5	6.7	2	1		↓						↓													
515	↓	↓	↓	75.8	4.4	2	0		↓		20	10	4	23	↓													
516	↓	↓	↓	66.9	10.2	2	0		↓		20	10	4	23	↓													
517	↓	↓	↓	63	2.2	2	0		↓		13		4	18	2													
518	↓	↓	↓	63.4	0.1	1	0		↓		7		4	23	3													
519	↓	↓	↓	63.1	10	1	0		↓		7	[illegible]	4	23	↓													
520	↓	↓	↓	81.1	9.9	2	8		↓		7	[illegible]	4	23	↓													
521	↓	↓	↓	91.4	1.1	3	0		↓		20	25	4	23	↓													
522	↓	↓	↓	60.6	5.9	1	0[a]		↓		6	6	4	18	2													
523	↓	↓	↓	86.3	0.4	1	1[a]		↓		6		4	18	2													
529	↓	↓	↓	69.7	14.2	2	0		↓		7		4	23	3													
532	↓	↓	↓	69.8	8.9	2	1		↓		6		4	18	2													
540	↓	↓	↓	74.5	14	1	0		↓		6	13	4	18	2													
542	↓	↓	↓	60.5	2.7	2	1[a]		↓		7		4	23	3													
543	↓	↓	↓	64	0.2	2	0		↓		7		4	23	↓													
544	↓	↓	↓	64.8	5.1	1	0[a]		↓		7	7	4	23	↓													
545	↓	↓	↓	69.9	2.0	1	7		↓		6	6	4	17	4													
564	↓	↓	↓	58.5	5	3	1		↓		6		4	18	2													
565	↓	↓	↓	63.4	8.4	2	1		↓		6		4	17	4													
701	2	78	77	27.3	7.8	2	1		↓		20	6	4	17	4													

[a] Exhaust coated with black soot

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-3-B CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm) Interior				Continuous CO Analyzer (ppm) Exterior				Type of Route
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
704	2	78	77	31.3	9.0	2	0		5		20	10	4	23	3													
705	↓	↓	↓	29.4	9.4	2	0		0		20		4	18	2													
706	↓	↓	↓	37	6.6	2	0		↓		6	6	4	17	4													
713	↓	↓	↓	29.3	8.3	2	0		↓		6	6	4	17	4													
714	↓	↓	↓	31.6	10.4	1	0		5																			
715	↓	↓	↓	27.7	17.1	2	0		0		20	7	4	23	3													
716	↓	↓	↓	36	0.9	2	0		↓		7	7	4	23	↓													
719	↓	↓	↓	30.3	4.2	2	0		↓		20	20	4	23	↓													
721	↓	↓	↓	35	12.2	2	2		↓		8	13	4	17	4	12.4			3.6									
722	↓	↓	↓	35.3	3.3	2	0		↓		6		4	17	4	18.9			3.6									
724	↓	↓	↓	36.7	9.6	2	0		↓		0		4	23	3													
725	↓	↓	↓	33.5	10.2	1	0		↓		6	13	4	16	2													

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-4-A   CITY: ____________   TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
3	2	60	67	113.	12	2	0			0	20		4	20														
4	2	60	60	90.5	9	2	0			0	7(7)[a,b]		4	20														
5	2	60	67	185.6	9	2	0			5																		
6	2	↓	↓	178	9	2	0			5	7		4	20														
7	↓	↓	↓	77.2	8.9	2	0			5	7		4	23														
8	↓	↓	↓	77	9	2	0			5	20		4	23														
25	↓	66	↓	168	9	2	0			0	7		4	20														
28	↓	↓	↓	164	10	2	0			0	4		4	20														
209	11	66	66	139.5	9.0	2	0			0	19		4	23														
211	11	↓	↓	140.6		1	8			0	10		4	10														
212	11	↓	↓	144	9	2	0			0	20		4	23														
213	11	↓	↓	154.3	9	2	0			0	0		4	20														
214	↓	↓	↓	156.4	9.1	2	0			5	3		4	20														
216	↓	↓	↓	150.8	9.0	2	0			0	0		4	20														
217	↓	↓	↓	140		1	8			0	20		4[d]	20														
218	↓	↓	↓	159.2		2	0			5	11		4	10														
220	↓	↓	↓	159.7	9.7	2	0			0																		
221	↓	↓	↓	165.5	9.0	2	0			5	10		4	20														
223	↓	↓	↓	159	10	2	0			0	3		4	23														
226	↓	↓	↓	137.4	9	2	0			5	10		4	23														
231	↓	↓	↓	153	9	2	0			5	21		4	20														
233	↓	↓	↓	161.4	9.0	2	0			0	20		4	20														
236	↓	↓	↓	149.3	8.7	2	0			0																		
239	↓	↓	↓	151.7	9	2	0			0	3		4	23														
240	↓	↓	↓	144.8	9	2	0			0	0		4	20														
244	↓	↓	↓	133	9	2	0			0	0		4	20														
249	↓	↓	↓	137.8	9	2	0			5	25[c]		4	23														
271	↓	↓	↓	138	9.4	2	0			5	7		4	23														
301	2	66	1960	109	8	2	0			0	21		4	20														
314	2	66	74	90.0	9.0	2	0			0	7		4	20														

a Redundant readings
b 2nd day reading 10 4/23
c Situated at airport for part of day
d Additional reading taken on 4/10 of 10ppm

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-4-A CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm) Interior				Continuous CO Analyzer (ppm) Exterior				Type of Route
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	Fixed
315	2	66	75	87.3	9	2	0		0																			
316	2			91.3	9.0	2	0		0		10		4	23														status
318				90	9	2	0		0		0		4	20														
319			↓	101		2	0		0		3		4	20														
320			76	84		1	8		0		10		4	10														
321			75	93.4		2	0		0		7		4	23														
322				99.1		2	0		0		10		4	10														
323			74	91.1	9	2	0		0		20		4	20						5		45^d		8.		>50		1.5ppm 6/20
324			75	92.5		1	8		5		12		4	10														
325			↓	99.1		1	8		5		11*	14	4	10														
362			76	79.9	9	2	0		0		3		4	23														
365				83.2	9.2	2	0		0		10*	10	4	23														
366				76.1	8						4^e		4	20														
367				76.7	9.2						19		4	23														
368	↓	↓	↓	76.3	8.8						7	3	4	23														
388	12a	76	78	24.1							10		4	10						2		13		4		39		2.1ppm 6/15
389	12			20.3							3(3)^b		4	20						3		17		7		38		2.6ppm 6/13
390				20.0							7(0)^b	4	4	20														
391				20.7		↓	↓		↓		3		4	23														
392				18.9		1	8		0		11		4	10														
395				19.6		2	0		0		10		4	23														
393				19.7		1	8		0		10		4	10														
394				23.9		1	8		0		10		4	10														
397	↓	↓	↓	19.3		2	0		0											2		19		4		29		1.4ppm 6/14

[a] Thomas Diesel

[b] Redundant readings: addtionally 16ppm found on 4/23/79

* Colocated Sample: (11)

* Colocated Sample: (10)

[c] Additional data from 4/10/79 13;;m

[d] Additional data 6/14 Int. Ave 9 Ext Ave .12
Int. Peak 21 Est Peak > 50

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-4-B   CITY: ______   TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
155	1	60	64	89	9	2	0		0		10		4	25														
161	↓	↓	↓	145.9	9	2	0		0		10		4	17														
165	↓	↓	↓	114	12	2	0		0		7		4	25														
166	↓	↓	↓	108	9.8	2	0		0		3		4	25														
168	↓	↓	↓	149	12	2	0		5		10[a]		4	17														
172	↓	↓	↓	97	9	2	0		0		0		4	25														
183	1	66	66	189	9	2	0		5		45		4	25														
189	↓	↓	↓	49.7	9	2	0		0		7		4	25						7		39		4		43		5/11[c] e
190	↓	↓	↓	188	9	2	0		0		10		4	17														
192	↓	↓	↓	69.9	9.9	2	0		0		20		4	25														
193	↓	↓	↓	172	8	2	0		5		10		4	17														
194	↓	↓	↓	94	9	2	0		5		22		4	25														
195	↓	↓	↓	85.8	9	2	0		5		20		4	25														
196	↓	↓	↓	93.4	9.8	2	0		5		7		4	25														
197	↓	↓	↓	168	15	2	0		5		10		4	17														
198	↓	↓	↓	134	9	2	0		5		10		4	17														
199	↓	↓	↓	147	9.1	2	0		5		10		4	17														
200	↓	↓	↓	48.3	9.2	2	0		0		23*	10	4	25														
202	↓	↓	↓	80.6	17.1	2	0		5		10		4	17						10(2)[e]		34		4		>50		6/11[d]
203	↓	36	↓	62.5	9.0	2	0		0		6		4	25														
205	3	78	70	38.3	9.	2,4	0		0		7		4	25														
241	11	66	66	137.6	9.1	2	0		0																			
260	11	↓	64	184.	10	2	0		5		10		4	17														
263	11	↓	66	104.6	9.1	2	0		5																			
275	1	36	71	157.7	9.1	2	0		5		10[b]		4	25														
329	1	66	75	78.5	16.9	2	0		0		11		4	17														
330	1	↓	↓	79.6	16.9	2	0		0		10		4	17														
331	1	↓	↓	83.9	8.9	2	0		0		3		4	25														
332	1	66	75	77.1	9.0	2	0		0		3		4	25														
342	↓	↓	↓	81.7	2.5	2	0		0		33		4	25						10		20		5		>50		5/10[c]

[a] Data on 4/17 was 10ppm
[b] Data on 4/17 was 10ppm
[c] Inside Exceeded outside CO conc. most of the time
* Colocated sample: (10)
[d] Fixed station reading = 0ppm
[e] Average during 1st half of run AM=10;
2nd half = 2ppm

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-4-B

CITY:

TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
343	1	66	75	81.9	17.1	2	0		0		11		4	17														
344	↓	↓	↓	85.5	9.0	2	0		0		51		4	25						3		12		4		> 50		5/11
345	↓	↓	↓	76.2	10	2	0		0		10		4	17														
346	↓	↓	↓	84.3	9	2	0		0																			
347	↓	↓	↓	77.0	9	2	0		0		20		4	25														
355	↓	↓	↓	81.5	9	2	0		0		50		4	25						5		> 50		3		> 50		5/10
356	↓	↓	↓	76.1	16.6	2	0		0		10		4	17														
357	↓	↓	↓	66.8	9	2,4	0		0		19		4	25						3.5		30		9		> 50		6/12[a]
396	12	76	78	11.2	11.2	2	0		0		3		4	25														
358	3	78	76	60.1	12	2,4	0		0		11		4	17														
359	3	78	77	71.1	9	2,4	0		0		10		4	17														
408	12	76	78	11.2	11.2	2	0		0		7(0)*	0	4	25														
409	12	↓	↓	12.3	12.3	2	0		0		10		4	17														
410	12	↓	↓	13.7	13.7	2	0		0		10		4	17														

a Fixed station levels averaged 1.7ppm

* Colocated sample

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-4-C   CITY: ____   TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm) Interior				Exterior				Type of Route
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
11	2	36	67	97	9	2	0		0		20	51	5	9														
12				18.9	9.2	2	0		5		19		5	9														
13				107	9	2	0		5		3		5	11														
14				85.6	9	2	0		0		10		5	9														
15				89.2	9.2	2	0		0		19		5	9						5		46						6/6/79
16				94.5	9	2	0		5		6		5	11														
17				0.7	0.7	2	0		0		11		4	9														
18				71.3	8.9	2	0		5		3(3)6		5	11														
141		60	63	101.4	8.6	2	0		5		20		5	9														
159	1	60	64	142		1			5		10		4	9														
185			66	81.5	9	2	0		0		19		5	9														
204		36		168		2	0		5		20		5	9														
206	11	66	66	53.9	8.9	2	0		0		10		5	10														
207				57	9	2	0		0		3	7	5	9														
210				56.7	9.2	2	0		0		4		5	10														
215				50.1	8.1	2	0		0		10		5	10														
222				143	13	2	0		5		11	10	4	9														
224				81		2	0		5		10		4	9														
225				97.1	9	2	0		5		22		5	10														
227				36.4		2	0		0		11		4	9														
228				54.6		2	0		5		10		5	10														
229				37.1	9.1	2	0		5		16		5	9														
230				22.7		1	0		2		10		4	9														
232				46.3		2	0		0		12		4	9														
234				73.3	9.3	2	0		0		7		5	9														
235				36.3	9	2	0		0		20		5	10														
237				154	9	2	0		5		10		4	9														
238				26.4	9.4	2	0		5		3		5	10														
242				24.7	9.2	2	0		5		17		5	10														
245				48.9	8.9	2	0		5		17		5	9														

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-4-C CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
246	11	66	66	42.1		2	0		5		10	10	4	9														
248	↓	↓	↓	37.3		2	0		0		10		4	9														
250	↓	↓	↓	42.9	8.9	2	0		5		7(7)	7	5	10														
251	↓	↓	↓	57.5		2	2		0		12		4	9														
252	↓	↓	↓	52.9		1	0		0		10		4	9														
255	↓	↓	↓	49.3	9.3	2	0		5		10		5	9														
256	↓	↓	↓	135	12				5		10		4	18														
257	↓	↓	↓	70.7	8.9	2	0		5		10	10	5	10														
258	↓	↓	↓	39.3	9.3	2	0		0		7		5	9														
259	↓	↓	↓	42.9	8.9	2	0		5		16		5	10														
262	↓	↓	↓	14.6	9.6	2	0		5		7(3)	3	5	11														
267	↓	↓	↓	44.3		2	0		5		11		4	9														
268	↓	↓	↓	33.5		2	0		0		11		4	9														
272	↓	12	↓	109	9	2	0		5		3		5	11														
276	2	36	72	18.6	9.6	2	0		0		19		5	9														
277	2	24	72	120.8	12	2	0		5		11		4	18														
278	2	78	72	107.6	11.8	4.2	0		0[a]		3		4	18														
279	↓	↓	↓	81.1	12	4,2	0		0		10		4	18														
280	↓	↓	↓	123	12	4,2	0		0		10		4	18														
281	↓	↓	↓	101		4,2	0		0		10		4	18														
282	1	66	72	17.2		1	0		0		10		4	9														
291	1	↓	↓	20.1	9.1	2	0		0		10[b]		4	9														
292	↓	36	73	10.6	9	2	0		0		7		5	9														
293	2	36	76	16.5	8.6	2	0		0		7		5	9														
308	↓	24	73	28.8	9	2	0		5		7		5	11														
309	↓	↓	↓	19.4	9	2	0		0		10		5	10														
310	↓	36	74	100	9	2	0		0		3		5	10														
311	↓	↓	↓	96	9	2	0		0		4		5	11														
312	↓	↓	↓	100	9	2	0		5		10		5	9														
313	↓	66	75	92.1	9	2	0		0		8		5	9														

[a] Dented rear

[b] Second day reading 3ppm 5/9/79

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-4-C

CITY:

TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
360	2	21	76	105	13.5	2	0		0		4		5	10														
363	↓	66	↓	95.6	9.1	2	0		0		7	6	5	9														
364	↓	↓	↓	78.7	9.2	2	0		5		3		5	11						8						> 50		
369	↓	24	77	154.8	9	2	0		0		9		5	10														
372	2^a	78	77	50.2	12.2	2	0		0		10		4	18														
373	2^a	↓	↓	48	12	2	0		0		10		4	18														
374	2^a	↓	↓	47.2	14	2	0		0		11		4	9														
375	2^a	↓	↓	51.1	11.1	2	0		0		10		4	18														
376	2^a	↓	↓	44.3	11.8	2	0		0		10^b		4	18														
377	2^a	↓	76	57.0	9	2	0		0		3		5	10														
378	2^a	↓	77	53.4	8.9	2	0		0		3		5	11														
380	2^a	↓	↓	42.8	8.9	2	0		0		4		5	11														
381	2^a	↓	↓	42.7	12	2	0		0		10	10	4	18														
382	2^a	↓	77	38.3		2	0		0		15		4	9														
383	2^a	↓	↓	39.5	9.0	2	0		0		7		5	10														
384	2^a	↓	↓	44.1	12.1	2	0		0		10		4	18														
385	2^a	↓	↓	44.9	9.9	2	0		0		4		5	11														
386	2^a	↓	↓	45.6	12	2	0		0		10		4	18														
403	12	76	78	24.4	09.4	2	0		0		3		5	10														
404	12	↓	↓	31.3	9.3	2	0		0		3		5	10														
405	↓	↓	↓	24.3	9.3	2	0		0		3		5	10														
406	↓	↓	↓	24.6	9.0	2	0		0		3		5	11														
407	↓	↓	↓	24.1	9.1	2	0		0		3		5	10														
520	4	66	70	10.6		1	0		0		10		4	9														
522	4	↓	↓	17.8		1	0		0		13	13	4	9														
10	2	36	67	84.8	9.3	2	0		0		19		5	9														
	↓	↓	↓																									
	↓	↓	↓																									
	↓	↓	↓																									
	↓	↓	↓																									

a Diesel

b Data also taken 4/9/79 as 10ppm

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-4-D CITY: TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts A B C	Stain Tube CO F	Stain Tube CO R	Stain Tube Date Mo	Stain Tube Date Day	Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date Mo	Personal Sampler Date Day	Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm) Interior Ave	Interior Loc	Interior Peak	Interior Loc	Exterior Ave.	Exterior Loc	Exterior Peak	Exterior Loc	Type of Route
9	2	36	67	93	13	2	0	5	14		4	16														
19	2	66	68	67.5	12.5	2	0	5	10		4	16														
20	2	↓	↓	71.2	9	2	0	0	10		4	26														
23	↓	↓	↓	63.1	9	2	0	5	31		4	26						18		>50						6/1
26	↓	↓	↓	61.2	9	2	0	5	20		4	26														
27	↓	↓	75	66.8	9	2	0	5																		
29	↓	↓	69	50.7	9	2	0	1,3,5	3		4	26								39				> 50		6/1[a]
30	↓	↓	↓	86.7	9	2	0	5	7		4	26														
31	↓	↓	68	71.4	9	2	0	0	8		4	26														
159	1	↓	64	42.9	10	2	0	0	63		4	26														
260	11	↓	66	19.3	9	2	0	5	7		4	26														
283	1	↓	72	20.2	9	2	0	0	10		4	26														
285	1	60	↓	18.7	2.2	2	0	5	11		4	16						10		>50						6/4
286	1	66	↓	15.4	10	2	0	5	10		4	26														
287	1	↓	↓	109	9	2	0	5	0		4	26														
288	↓	↓	↓	12.9	0.9	2	0	5	7		4	26														
290	↓	↓	↓	109.7	9.7	2	0	5	4		4	26														
294	2	36	68	98	12.3	2	0	2,5	12		4	16														
295	2	66	73	108	8.1	2	0	0	0	7	4	26														
296	↓	↓	↓	108	10	2	0	0	12		4	16														
297	↓	↓	↓	104	14	2	0	0																		
298	↓	↓	↓			2	0	0	12		4	16														
299	↓	↓	↓	97.4	8.9	2	0	0	10		4	26														
300	↓	↓	↓	108	9	2	0	5	3		4	26														
302	↓	↓	↓	119	19	2	0	0	20		4	26														
303	↓	↓	↓	133.8		2	0	5	11		4	16														
304	↓	↓	↓	98.7	12.2	1	0	8	11	10	4	16														
305	↓	↓	↓	97.7	12.1	2	0	0	10		4	16														
306	↓	↓	↓	102.9	3.9	2	0	0	0(0)0		4	26														
307	↓	↓	↓	106.3	12.3	2	0	0	12		4	16														

[a] Run included periods in line with other buses, idling.

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-4-D CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
326	2	66	75	91.1	12.1	2	0		0																			
327				92.9	9.0	2	0		0																			
328				88.5	10.0	2	0		0		10		4	16														
333				80.4	0	2	0		0		11		4	16														
334				82.0	9.0	2	0		0		7		4	26														
336				80.6	9.0	2	0		0																			
337				79.4	9.4	2	0		0		4		4	26														
338				75.7	9.0	2	0		0		69		4	26														
339				70.0	9.0	2	0		2		48		4	26						25[a]		50						5/31
340			74	66.8	14	2	0		0		11		4	16														
341			75	87.4	8.9	2	0		0		3		4	26														
348				80.8	9.0	2	0		0		6		4	26														
349				75.5	9.0	2	0		0		3		4	26														
350				65.5	9.1	2	0		0		0		4	26														
351				73.4	8.8	2	0		0																			
352				89.5	9.0	2	0		0		6		4	26														
361			76	75.6	12.1	2	0		0		11		4	16														
387	12	76	78	19.9	9.9	2	0		0		3(3)*7		4	26														
398				15	15	2	0		0		12		4	16														
399				14.9	1.5	2	0		0		11		4	16														
400				12.1	9.1	2	0		0		0		4	26														
401				15.9		2	0		0		11		4	16														
411				14.1	10.1	2	0		0		4		4	26														

a Average taken at rear of vehicle over 1 hr.

* Cclocated sample

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-5-A CITY: ______ TYPE OF VEHICLE : BUS

All Vehicles Int'l 1977 2-Dr. 37' 63 Pass Model 1703

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
101		63		18	287	2	2	0			20	8	5	1														9
102		↓		16	298	2	0	0			7	7	↓															↓
103		↓		19	285	2	0	0			20	10	↓															↓
104		↓		20	273	1	2[3]	0			7	10	↓															↓
105		↓		17	274	1	2	0			7	7	↓			10.5[8]	5	18										↓
106		↓		16	182	2	0	0			7	5	↓															↓
107		↓		21	1076	1	2	0			5	20	↓		AVERAGE FIXED SITE LEVELS: 3 SITES 2.5 ppm 1.7 ppm 1.3 ppm													↓
108		↓		18	1101	2	9	1[5]			7	7	↓															↓
109		↓		16	350	2	1[4]	0			3	10	↓															↓
110		↓		19	1298	2	0	0			9	10	↓			4.5	5	18										↓
111		↓		19	931	2	0	0			5	20	↓			0.9	5	18										↓
112		↓		20	120	2	2	0			7	3	↓															↓
113		↓		20	820	2	0	1			10	7	↓			2.3	5	19										↓
114		↓		19	808	2	0	0			7	7	↓															↓
115[1]		↓		20	832	3	0	0			20	3	↓			5.5[7]	5	18		6		22		< 10		52		↓
116		↓		23	947	2	0	0			9	10	↓			4.0	5	18										↓
117		↓		25	723	2	0	1			10	7	↓															↓
118		↓		18	75	2	0	0			5	3	↓															↓
119		↓		19	47	2	0	4[6]			9	10	↓															↓
120		↓		21	50	2	1	0			7	7	↓															↓
121		↓		22	55	2	0	0			9	2	↓															↓
122		↓		20	46	2	0	0			10	20	↓															↓
123[2]		↓		21	807	2	2	1			2	9	↓															↓
124		↓		15	20	2	0	0			7	4	↓															↓
125		↓		18	17	2	0	0			7	5	↓															↓
126		↓		18	1008	2	0	0			7	3	↓															↓
127		↓		17	55	1	0	1			5	7	↓															↓
128		↓		23	6135	2	0	0			9	9	↓															↓
201		↓		18	215	1	2	1			7	10	5	3														5
202		↓		16	105	2	2	1			9	7	5	3														5

1 Driver Complaint
2 "Tailpipe spits gasoline"
3 Rust

4 Flattened
5 Front door seal
6 Rear Window Ajar

7 Second sampler also used - 4.0ppm
8 Second day 9.6ppm 5/19

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-5-A CITY: TYPE OF VEHICLE : BUS

All Vehicles Int'l 1977 2-Dr. 37' 63 Pass Model 1703

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
203				18	100	2	0	0			18	7	5	3	AVERAGE FIXED SITES 3.1ppm:3.0ppm:1.6ppm													5
204					252						5	7																
205				20	589						10	9																
206				21	3132	1	3	3			9	7																
207				16	267	2	0	0			10	9				4.4	5	19										
208				19	610	2	0	1			7	9																
209				23	393	2	2	0			10	10																
210				21	290	2	0	3			20	5																
211				21	293	2	0	0			23	3										32		~10		68		
212				19	2695	3	0	0			5	7																
213				14	275	2	2	0			10	7																
301				20	310	2	6	0			9	3	5	2	AVERAGE FIXED SITE LEVELS 2.1ppm: 4.7ppm: 0.8ppm													7
302				24	330	1	2	3			9	10																
303				24	324	2	0	1			3	7																
304				24	876	2	0	0			7	7																
305				23	326	2	2	0			7	9																
306				23	373	2	0	24			9	7																
307				21	362	1	0	0			10	10																
308				22	224	2	0	0			7	7				7.6	5	19										
309				24	517	2	0	0				7																
310				16	395	2	0	0			7	9																
311				23	359	2	0	0			20	7																
312				21	438	2	0	0			5	7																
313				19	287	2	0	0			9	7																
314				22	442	2	2.6	0			10	32																
315				23	335	2	0	0			7	22																
316				21	316	2	0	0			7	9																
317				24	344	2	2	0			7	3																
318				23	304	2	2	0			9	10																
319				22	425	2	2	13			10	9																

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-5-A

CITY:

TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	B	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
320				24	338	1	2	0			10	32	5	2														
321				24	297	2	0	0			7	9								~3		~10		~10		43		7
322				21	206	2	2	0.			7	7																
323				23	1059	2	0	3			7	3																
324				23	207	2	0	0			10	7				3.7[2]	5	18										
325				24	5447	2	6	3			10	7																
326				24	1091	2	0	1-			7	7																
327				22	396	2	0	0			7	23																
401				17	811	2	6	0			7	10																
402				22	3394	1	0	0			5	3																6
403				19	1036	2	6	0			10	10																
404				18	928	2	0	0			7	7																
405				23	1628	2	0	0			26	7																
406				19	1182	2	0	0			9	7								6		34		10		22		
407				23	923	2	0	0			7	7																
408				20	1064	2	0	0			10	10																
409				20	1161	2	0	2	3	4	7	4																
410				20	942	2	0	0			7	10																
411				22	963	2	6	0			9	7																
412				23	1082	2	0	0			7	20				10.3	5	19										
413				21	938	2	0	0			9	5				3.1	5	19										
414				20	834	2	6	0			7	9																
415				13	987	2	0	0			10	8																
416				20	941	1	0	1			10	7																

AVERAGE FIXED SITE LEVELS 3 SITES
2.1ppm: 4.7ppm: 0.8ppm

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1 Exhaust trapped by bumper

2 Second day reading 4.6 5/19/79

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-6-A

CITY:

TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
30	6	64	70	30	NO DATA	1	0	1	4		10																	
277	8	65	75	32		2	6	0			9	7																
279	7			51		2	0	1	3		18	10				9.3	6	8	2.8									
280	7			33		1	2	0			10																	
281	8			40		2	7	1	3		10	7																
283	7			40		1	0	1			7	9																
284	8			31		2	0	1			7	7																
285	8			31		2	2	1			7	9																
288	7			32		2	3	0			7	7																
290	7			22		1	2	0			7	4																
292	7			25		2	7	0			8	10																
293	7			40		2	0	0			7																	
295	5			49		2	2	1			7	7				7.9	6	7	4.6									
297	7			38		2	6	1			18	20				25.3	6	7	5.8[b]	4[c]		18[c]		9[c]		76[c]		
301	9		73	122		1	2.3	1			10	19				29.1	6	8	4.3									
500	8		75	15		2	2	0			7	8																
501	8			34		2	6	1			7	7																
503	7			66		2	0	0				8																
505	7			31		1	0	0			7	7																
528	6		70	68			2.6	0			5	7																
4126	6	64	70	115			6	1	8		3	7																
7101	10	63	71	106			1	5			9	17																
7102		58		88			2.6	1			7	9																
7203				117			1.6	1	5		6	7																
7204				118			0	6			17	17																
7205				150			6	0			3	6																
7207				X[a]		X	X	X			9	9																
7219				71		1	6	1			8	18																
7224		65	72	82		1	0	1				10				13.6	6	7	4.6									
7225		65	72	51		1	2.6	1			18	7																

[a] X = No data

[b] Vehicle No. 295

[c] Interior and exterior measurements made on separate runs on same day

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE,
PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-6-A

CITY:

TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
7226	10	65	72	66	X	1	2,6	0			10	8																
7227				65			2	0			7	16																
7231				75			0	1	2		9	9				15.5	6	7	4.1									
7237				85			2,4,6	1			20	23																
7238				79			0	1																				
7242	↓	↓	↓	64			2	1	2	6	27	23																
7302	9	61	73	137			6	1	5		23	23				7.0	6	7	4.3									
7306	9	61	73	82			0	8			9	7																
7307	9	61	73	67			2	1	8		8	7																
7501	7	65	75	48			0	1				7																
7502	7			51			6	1			10	7																
7504	9			51		↓	0	1	3							67.9	6	7	4.3									
7505				X		X	X		X			3								6^c		20^c		10^c		100		
7507				27		2	7	1			7	7				15.5	6	7	4.3									
7508				41		2	6	0			5	7																
7509				50		2	2	0			10	10				13.0	6	7	4.6									
7510				49		1	0	1			10	10				30.0	6	8	3.8									
7511				54		1	4,6	0			7	7																
7512				53		1	2,3	1			10	10																
7613				52		2	0	0			10	9																
7614				54		1	0	0			10	8																
7615				39		1	6	0			7	7																
7616				48		2	0	3			20	20																
7617				43		2	6	0			7																	
7618				41		2	2	1			9	9																
7619				37		2	2	3			10	7																
7620				48		2	6	3			9	9																
7621				X		X	X	X			10	8																
7622				52		1	6	0			4					8.0	6	8	4.2									
7623	↓	↓	↓	45	↓	1	0	0			8	5																

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: B-6-A CITY: ______ TYPE OF VEHICLE : BUS

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
7624	9	65	75	46	X	1	8	1			7	7																
7625				45		1	0	1			8	8																
7626				38		2	6	0			26	26																
7627				41		2	3.6	0			9	9				46.1	6	8	2.8									
7628				40		1	8	0																				
7629		↓		50		1	6	1			8	18																
7630		60		34		1	0	1			10	18																
7631		65		47		1	4	0			8																	
7632				54		2	6	3			18	8																
7633				50		1	0	1			18	8																
7634				43		1	0	3			8	18																
7635				38		2	0	3			7	8																
7636				30		1	2	0			7	7																
7637				40		2	0	1			7	9																
7638				32		2	2	1			8	20									8^c		62^c		9^c		100^c		
7640				40		1	0	0			7	7																
7641				54		2	0	0			8	8				38.1	6	8	3.2									
7642				54		1	0	0			8	8																
7643				48		1	0	0			10	9																
7503	↓	↓	↓	47	↓	2	0	1			7	7																

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE,
PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: T-1-A CITY: ________ TYPE OF VEHICLE : TAXI

All vehicles are checker cabs (Chevrolet 250 CID engines)
All vehicles have tailpipe location 1 and intrusion point 8 (A zero means no additional points)

Veh. I.D. No.	Make of Vehicle	No. of Passen-gers	Year	Mileage in 1000s	Mileage Since Tune-Up in 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intru-sion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
201			76	202	0.04		0	7			25		4	27	2													
202			↓	216	9.3		↓	1	5		27		4	17	3													
203			↓	220	1.6		↓	7			26		4	16	3													
204			↓	198	2.2		↓	0																				
205			↓	229	2.3		↓	7			22		4	24	3													
206			↓	213	3.1		↓	0			26		4	17	3													
207			↓	213	0		↓	0			19		4	27	2	8.2	5	2	2.3									
208			↓	201	6.7		↓	7																				
209			↓	217	1.1		↓	2			26		4	17	2													
210			↓	237	3.1		↓	2			32		4	17	3													
211			↓	220	3.0		↓	0																				
212			↓	204	3.2		↓	0			10		4	16	3													
214			↓	188	1.2		↓	1	2	7	20		4	26	2	1.6	4	30	1.9									
216			↓	199	7.7		↓	1	5	7	54		4	16	3													
218			↓	207	1.4		↓	7			22		4	27	2	5.9	5	3	1.0									
219			↓	190	8.7		↓	7			15		4	17	3													
220			↓	169	2.0		↓	0			34		4	17	3	6.6	5	1	2.3			43				33		
222			78	28	11.2		↓	2			15		4	17	3													
223			76	176	0		1	0			18		4	26	2													
224			↓	158	7.2		0	0			31		4	17	3	23.7	5	2	2.3									
225			↓	184	9.6		0	1			18		4	26	2													
226			↓	181	4.5		1	1	3	5	16		4	26	2													
227			↓	169	5.5		0	5	7		17		4	26	2													
228			↓	189	2.6		↓	0			18		4	23	2													
229			↓	190	6.6		↓	7			17		4	23	2	36.3	5	3	1.0									
230			↓	205	5.7		↓	1	2	7						13.6	4	30	1.9									
231			↓	173	2.3		↓	2	7	9																		
232			↓	188	9.6		↓	1	2		26		4	16	3													
233			↓	193	10.5		↓	0			23		4	23	2													
234			↓	201	0.7		↓	1	2	7	10		4	16	2													

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: T-1-A

CITY:

TYPE OF VEHICLE : TAXI

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage X1000	Mileage Since Tune-Up X1000	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
								A	B	C	F	R	Mo	Day			Mo	Day		Interior				Exterior				
																				Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
236			76	160	0.8		0	1	2		32		4	23	2													
237				209	6.0			2	7		31		4	17	2													
238				159	9.3			1	2	7																		
239				186	6.9			2			24		4	17	3													
240				185	1.0			7			26		4	16	3													
241				191	2.7			0																				
242				191	8.0			2	7		24		4	27	2													
243				192	4.7			1			22		4	27	2													
244				189	0			1	2	7	14		4	16	3													
245				190	2.3			2			31		5	18	4													
246			77	185	0		1	5	7	9	22		5	18	4													
247				97	6.6		0	7			25		4	16	2													
248				180	0			2	7		35		4	23	2													
250				188	3.0			1	2	7	29		4	23	2	27.9	5	3	1.0									
251				151	4.9			2			19		4	27	2													
253				158	0			2			26		4	16	2													
254				153	2.9			1	2	7	18		4	24	3													
256				139	3.3			2	7		25		5	18	4													
257				152	4.5			7			34		4	27	2													
259				132	2.6			1	2	5	21		4	23	2													
260				128	7.4			7			25		4	16	2													
261				171	9.1		1	3	5		18		4	26														
262				172	10.4		0	0			27		4	24	3													
263				112	3.9		0	9			26		4	16	3													
264				153	5.4		5	3	5		28		4	26	2													
265				163	0		0	0			30		4	23	2													
266				173	8.6			2			19		4	23	2													
267				148	3.9			2	7		19		4	24	3													
268			78	146	2.0			1	2		22		4	27	2													
269			77	138	7.6		5	7																				

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: T-1-A CITY: ____________ TYPE OF VEHICLE : TAXI

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
270			77	145	9.8		0	2	5		18		4	27	2													
271			77	139	1.7		↓	0			31		4	17	4													
272			77	116	6.1		↓	1	2	5	25		4	27	2													
273			78	75	1.7		↓	1	5																			
274			77	156	7.7		↓	0			22		4	17	3	39.2	5	3	1.0									
275			↓	138	2.8		↓	1	7		8		4	26	2	6.1	5	1	1.0									
277			↓	123	3.7		↓	2			17		4	26	2													
278			↓	110	0.5		↓	1	2		20		4	23	2													
279			↓	131	9.4		↓	0			38		4	17	3													
280			↓	122	7.8		↓	1	2	5																		
281			↓	115	0.6		5	7			21		4	26	2													
282			↓	98	7.3		0	7			17		4	26	2													
283			↓	116	2.1		0	2			22		4	17	3													
284			↓	137	1.1		5	0			19		4	23	2	17.3	5	3	3.5									
285			↓	121	3.1		1	2	3		32		4	18	1													
286			↓	109	1.6		0	2	5																			
287			↓	131	4.2		↓	0			29		4	26	2													
288			↓	116	5.4		↓	7			18		4	26	2													
289			↓	110	0.6		↓	0			21		4	26	2	13.8[a]	5	3	1.0									
291			↓	116	3.4		↓	0			13		4	16	3	0.8	4	30	2.2									
292			78	81	10.6		↓	1			14		4	18	1	6.9	5	3	3.3									
298			↓	72	4.7		↓	7			24		4	26	2	8.6	4	30	1.9									
299			↓	86	1.6		↓	7			10		4	16	2													
302			↓	80	1.0		↓	1	5	7	22		4	16	2													
303			↓	73	4.7		↓	0			15		4	17	2													
304			↓	53	7.4		↓	1	2																			
306			↓	19	3.6		↓	2	4		26		4	16	3													
307			↓	83	9.3		↓	2			10		4	17	2													
308			↓	74	4.3		↓	1	5	7																		
311			↓	102	9.0		↓	1			25		4	16	2													

[a] Personal sampler may have been defective

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: T-1-A CITY: TYPE OF VEHICLE : TAXI

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
313			78	69	0		2	2			11		4	16	2													
314			78	57	1.6		0	0			24		4	23	2													
317			78	53	0			2	4		31		4	17	3	15.3	4	30	2.0									
318			79	2	2.1			0																				
320			78	53	10.4			1			18		4	23	2													
324				89	3.4			1			26		4	18	1													
326				61	5.2			2			19		4	24	3													
327				49	3.2			0			7		4	17	2													
332				77	9.2			7			22		4	23	2													
335				57	6.7			2			25		5	18	4													
344				85	6.8			1	7		23		4	26	2													
364				17	5.4			2			26		4	16	2													
366				51	9.4			0			26		4	18	1													
369				56	3.0			2			37		4	18	1	30.5	5	3	1.0									
379				32	3.6			1	2	7	20		4	23	2													
388				37	0			0																				
399				72	1.7			3	4		17		4	26	2													
406			79	8	8.0			2			39		4	16	2													
423			78	72	3.1			2			20		4	24	3													
501				22	10.3			0			19		4	26	2													
510				69	8.7			1			15		4	16	2													
545				52	10.3			0			10		4	26	3													
588				83	10.2			0			31		4	23	2					9.2		35		17.6		>100		
601			74	353	4.9			7			14		4	16	2													
605				324	4.4			1	5	7	19		5	18	4													
606				291	9.0			1	5	7	11		4	16	2													
610				330	10.4			7			17		4	26	2	11,1	5	2	3.6									
611			79	2	2.3			0			39		4	16	2							>50				>100		
613			74	65	1.1			0			33		4	27	2													
614			74	4	4.3			2	7																			

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: T-1-A CITY: TYPE OF VEHICLE : TAXI

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
616			74	320	7.7		0	0			26		4	26	2	5.2	5	3	1.0									
617				318	3.5			2	7		26		4	16	3													
620				328	6.9			0			24		5	18	4													
624				328	5.9			7			7		4	26	2													
625				282	0.4			1	2	7	24		4	16	3	48.0	5	3	1.0									
626				330	8.6			1			24		4	26	2													
628				293	9.1			1	2	5	22		4	26	2													
629				390	2.3			0			26		4	16	3													
631				343	0		↓	2	7		26[a]		4	16	2													
633				312	0.5		2	1	2	7	26		4	18	1													
634				313	1.9		0	1	5	7	31		4	16	2													
637				309	0.2		0	1	5	7	18		5	18	4													
639				319	6.3		2	5																				
640			↓	300	0		0	1	2	5																		
641			no data	309	9.7			1	2		39		4	23	2	7.3	5	3	3.7									
643			74	298	9.5			1	5	7	27		4	24	3	13.8[c]	5	2	3.1									
645				239	3.3			1	2	7	21		4	26	2													
647				313	8.2			2			20		4	24	3													
648				282	1.2			2		9	10		4	16	2													
649			↓	306	110.3			1	5	7	25		4	23	2	8.9	5	3	3.1									
650			78	52	9.8			5			15		4	17	2													
651			no data	28	0.9			1	2	7	28		4	24	3													
653			74	276	0.3			1	2		31		5	18	4													
654				311	5.6			1	5	7	11		4	18	1													
655				120	10.2			1	2		18		4	27	2	13.4	5	2	2.3									
656				274	8.8			1	5	7	17[b]		4	26	4													
657				305	8.9			7			17		4	26	2													
658				293	10.0			1																				
660				303	1.2			2	7		22		4	27	2													
661			↓	279	10.0		↓	1	2	7	28		4	16	3													

[a] Second reading of 11ppm on 4/17; Ambient CO = 3ppm

[b] Second reading of 23ppm on 4/26

[c] Personal sampler unit may have been defective

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: T-1-A

CITY:

TYPE OF VEHICLE : TAXI

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage IN 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts A	Intrusion Pts B	Intrusion Pts C	Stain Tube CO F	Stain Tube CO R	Stain Tube Date Mo	Stain Tube Date Day	Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date Mo	Personal Sampler Date Day	Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm) Interior Ave	Interior Loc	Interior Peak	Interior Loc	Exterior Ave.	Exterior Loc	Exterior Peak	Exterior Loc	Type of Route
662			74	290	0.8	1	0	1	3	7	27		4	17	2													
663				308	2.8			1	5	7	28		4	23	2													
664				322	5.8			0			27		4	26	2													
666				343	7.6			1	2	5																		
667				274	5.2			0			28		4	16	3													
668				298	0.7			7			27		4	17	3	5.3	5	3	1.0									
669				267	9.5			7			25		4	16	2													
671				302	0			7			22		4	17	4	11.9	4	30	2.0									
672				151	0.5[a]			2	7		11		4	16	3													
673				311	1.7			1	2	4	20		4	26	2													
674				281	4.1			1	2	5	24		4	26	2	8.2[c]	5	2	3.5									
675				302	7.0			2	7		20		4	23	2													
677				308	11.0			0			32		4	18	1													
679				357	1.8			3	8		20		5	18	4													
683				306	0.5			1	5	7																		
684				307	7.2			1	7		23		4	23	2													
685				300	5.2			1	5	7	47		4	16	3													
686				334	2.4			2	7		26		4	16	2	34.6	5	3	1.0			31				50		
687				328	1.6			2	7		21		4	23	2													
688			78	294	0.2			1	2		25		4	18	1													
690			74	297	7.1			1	7		20		2	26	2	3.8[c]	5	1	2.3									
691				41	3.7[a]			2	7		28		4	16	2													
692				291	6.0			2	7		17		4	26	2													
693				284	4.0			1	2		20		4	27	2													
694				318	1.9			0																				
696				283	8.4			1	5	7	31		4	16	2													
699				288	5.3			2	7		16		4	26	2													
701[b]				323	4.6			1	5	9	13		4	16	3													
702				190	8.0[a]			1	2	5												>50				>50		
703				300				2	7		25		4	24	3													

a Mileage since overhaul
b This cab had a cracked windshield
c Personal sampler unit may have been defective.

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: T-1-A CITY: TYPE OF VEHICLE : TAXI

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
704			74	282	9.8	1	0	2	7																			
705			74	316	9.7	↓	↓	1	7		28		4	16	3													
706			78	64	8.5	↓	↓	0			19		4	24	3													
707			74	311	6.0	↓	↓	1	5	7	17		4	27	2	6.8	5	1	2.3									
708			↓	283	6.8	↓	↓	7			22		4	26	2													
709			↓	307	1.4	↓	↓	1	2	7																		
710			↓	296	6.9	↓	↓	1	2		33		4	23	2													
713			↓	309	0.8	↓	↓	1	2	7	24		4	16	3													
714			↓	317	0.7	↓	↓	1	7		13		4	16	3													
715			↓	289	8.7	↓	↓	1	5	7																		
716			↓	326	0	↓	↓	1	5	7	35		4	23	2													
718			↓	295	8.3	↓	↓	0			17		4	26	2													
719			↓	318	1.1	↓	↓	1	7		29		4	24	3	8.2	5	3	1.0									
723			↓	311	6.4	↓	↓	7			21		4	23	2													
726			↓	293	100.5[a]	↓	↓	1	2	7																		
727			↓	316	0	↓	↓	1			30		4	24	3													
728			↓	323	4.3	↓	↓	7			22		4	16	2													
730			↓	295	13.6	↓	2	1	5	7																		
731			↓	298	1.5	↓	0	1	5	7	27		4	24	3													
732			↓	309	9.2	↓	↓	1	5	7	20		4	27	2													
733			78	70	11.9	↓	↓	1	2																			
734			74	299	4.3	↓	↓	1	5	7																		
735			↓	312	6.7	↓	↓	1	5	7	30		4	24	3													
736			↓	285	3.3	↓	↓	1	7		24		4	24	3													
739			↓	296	0	↓	↓	1	7		26		4	17	3													
740			↓	314	3.2	↓	↓	1	2	7	28		4	24	3													
741			↓	297	3.0	↓	↓	3	8																			
742			↓	303	0.5	↓	↓	1	5	7	4		4	16	3	6.3	5	2	2.3									
743			↓	310	9.3	↓	↓	1	5	7	21		4	26	2													
745			↓	286	1.6	↓	↓	2	7		18		4	23	2	0.6	4	30	2.0									

[a] This value questionable

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: T-1-A CITY: ______ TYPE OF VEHICLE : TAXI

Veh. I.D. No.	Make of Vehicle	No. of Passen-gers	Year	Mileage in 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intru-sion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
746			74	264	8.6	1	0	7			21		4	26	2													
748				300	3.6			1	2	7	26		4	27	2													
749				37[a]	11.0			1	5	7	35		4	23	2													
750				330	9.4			1	2	7	23		5	18	4													
751				291	8.0			1	5	7	29		4	23	2													
752				290	5.0			7			25		4	23	2													
753				17[a]	1.0			0			24		4	16	3													
756				329	0.9			1	2		31		4	18	1													
757				309	0			7			18		4	27	2													
758				333	?			2	7		21		5	18	4													
759				341	2.7			1			26		4	17	3													
760				249	3.8			0	3		19		4	26	2	8.8	5	1	2.3									
761				307	4.2			0			13		4	17	2													
762				311	2.8			1	2	7	26		4	26	2													
763				27[a]	4.5			7			30		4	16	2													
771			78	47	7.5			1			27		4	26	2													
801				83	9.1			0			31		4	16	3													
802				74	5.9			1	2		19		4	23	2													
808				55	3.3		4	0			15		4	16	2													
810				19	4.8		0	0			15		4	16	3	8.2	5	2	2.3									
811				58	5.5		6	0			18		4	24	3	15.9	4	30	2.2									
818				86	?		0	0	2		26[b]		4	17	3													
825				83	5.6			7			17		5	18	4													
848				47	1.5			2	7		27[c]		4	17	3													
850				67	0.6			0	2		11		4	17	2													
877				94	8.6			1	2		27		4	16	3													
880				48	0			0			15[d]		4	16	3													
882			79	9	8.8		2	0			11[e]		4	16	2													
888			78	95	0.7		0	0			39		5	18	4													
890			78	45	8.9		0	0			22[f]		4	16	2													

[a] Mileage since overhaul

[b] Second measurement: 6ppm on 4-24-79; Amb Co = 3ppm

[c] Second measurement: 22ppm on 4-23-79; Amb Co = 2ppm

[d] Second measurement: 22ppm on 4-23-79; Amb Co = 2ppm

[e] Second measurement: 6ppm on 4-23-79; Amb Co = 2ppm

[f] Second measurement: 22ppm on 4-24-79; Amb Co = 4ppm

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: T-1-A CITY: ______ TYPE OF VEHICLE : TAXI

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
892			78	38	10.1	1	0	0			27		4	17	2													
898			↓	45	3.8	1	0	2			22		4	16	2	11.6	5	2	3.5									
899			↓	90	9.4	1	0	0			15		4	17	3	6.8	4	30	2.0									

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: P-1-A through D CITY: ______ TYPE OF VEHICLE : POLICE

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm) Interior				Continuous CO Analyzer (ppm) Exterior				Type of Route
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
374	2		78	24	9.7	2	0	0			22		4	30	3													
374	2		78	24	9.7	2	0	↓			4	7	6	19	2													
384	6		77	76	10.0	↓	↓	↓			17		5	2	6													
385	2		78	16	10.0	↓	↓	↓			17		4	30	3													
389	3		78	17	10.0	↓	↓	↓			17		5	3	2													
389	3		78	17	10.0	↓	↓	↓			22		6	14	5	16.9	6	14	4.5									
409	6		78	69	10.0	↓	↓	↓			17	17	5	2	6													
412	6		77	71	10.4	↓	↓	↓			7	4	6	20	2													
416	3		78	25	10.2	↓	↓	↓			17	4	6	19	2													
421	6		77	78	10.2	↓	↓	↓			7	7	6	20	2													
448	2		78	19	10.0	↓	↓	↓			7		6	14	5													
455	5		78	31	10.1	4	↓	↓			7	7	5	3	2													
456	3		78	34	10.0	2	↓	↓			22		6	14	5	7.8	6	14	4.5									
456	3		78	34	10.0	↓	↓	↓			17		5	3	2													
479	2		78	16	10.0	↓	↓	↓			7		6	11	2					15[b]		> 50[b]						(5/22)
479	2		78	16	10.0	↓	↓	↓			28	28	6	11	2													
486	3		78	31	10.0	↓	↓	↓			4		6	22	5													
486	3		78	31	10.0	↓	↓	↓			17		6	11	2													
490	6		77	73	10.3	↓	↓	↓			4	4	6	19	2													
497	3		78	24	10.1	↓	↓	↓			7		5	1	4													
497	3		78	24	10.1	↓	↓	↓			4		6	14	5													
500	3		78	28	10.0	↓	↓	↓			22	36	6	22	5	19.8	6	14	4.4									
500	3		78	28	10.0	↓	↓	↓			7		5	13	3													
486	3		78	31	10.0	↓	↓	↓			17		5	3	2													
[a] 504	3		78	35	10.0	↓	↓	↓			4	4	6	20	2													
513	6		↓	69	10.0	↓	↓	↓			17	22	4	30	3													
514	3		↓	10	10.0	↓	↓	↓																				
521	3		↓	23	9.9	↓	↓	↓			22	22	6	21	2	6.0	6	13	3.6									
521	3		↓	23	9.9	↓	↓	↓			17		6	21	2													
522	3		↓	27	19.9	↓	↓	↓			22		5	3	2													

a Testing Gasohol
b Vehicle testing gasohol

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: P-1-A through D CITY: ____________ TYPE OF VEHICLE : POLICE

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
524	3		78	19	10.0	2	0	0			17		5	2	6													
525	3			30	9.7	2					7	17	6	21	2													
548	3			24	10.0	2					7	7	6	20	2													
548	3			24	10.0	2					7		5	1	4													
552	5			64	10.0	4					7		5	1	4													
555	3			31	10.0	2					17	7	6	21	2													
575	3			36	9.9						17		5	2	6	1.4	6	13	2.1									
575	3			36	9.9						7		6	13	2													
576	6			71	10.0						4		5	3	2													
576	6			71							4		5	1	4													
577	6		77	65							7	7	6	20	2													
579	3		78	36							17		5	2	6													
579	3			36							17		6	13	2													
592	6			77							17		6	14	5													
592	6			77							4		5	3	2													
535											4		6	13	2													
451	3		78	27	17						22		6	13	2	6.1	6	13	3.6	10[c]	rear	15[c]		5[c]		> 50[c]		
425											7		6	11	2	7.6	6	11	1.7									
441		NOT INSPECTED									17		6	11	2													
[a] 15	1		75	95	10.0	2	0	0			86		5	1						25		>100		12				5/24
35	2		79	21	10.0	1		0			22		4	30	3													
35	2		79	21	10.0	1		0			7	7	6	19	2													
[b] 37	4		76	68	10.1	1	8	8			17	28	5	1	4					~40		>100		~20		>100		5/25
45	3		78	27	10.0	2	0	0			7		6	14	5													
45	3			27	10.0	2					4		5	3	2													
45	3			27	10.0	2					7	4	6	22	5	0.6	6	14	4.4									
51	3			24	10.1	2					17		5	2	6													
55	5			51	9.9	4					22		5	2	6													
71	5			41	10.0	4					17		5	2	6													
71	5			41	10.0	4					4		6	13	2													

a Headaches reported by driver

b Ambulance driver smells fumes

c Only one continuous analyzer channel operating
Readings switched to and from interior/exterior

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: P-1-A through D CITY: TYPE OF VEHICLE : POLICE

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
82	5		78	32	10.0	4	0	0			7		5	2	6													
82	5		↓	32		4	↓	↓			7		5	2	6													
115	3		↓	28		2	↓	↓			7	7	6	19	2	2.6	6	11	1.2									
118	5		↓	53	10.2	4	↓	↓			4		5	3	2													
118	5		↓	53	10.2	4	↓	↓			7		6	14	5													
134	2		↓	22	10.0	2	↓	↓			17		4	30	3													
138	5		79	4	3.8	4	↓	↓			17		4	30	3													
140	5		78			4	↓	↓			6	4	6	19	2													
141	2		78	82	10.0	2	↓	↓			22		4	30	3													
161	5		78	33	9.0	4	↓	↓			4	4	5	3	2													
167	6		72	72	9.1	2	↓	↓			17	17	6	20	2													
210	2		78	125	9.0	2	↓	0			17		4	30	3													
216	3		↓	26	10.0	2	↓	↓			7		5	3	2													
216	3		↓	26	10.0	2	↓	↓			7		6	14	5	21.4	6	14	4.5									
218	3		↓	34	10.1	2	↓	↓			0		5	1	4													
223	1		75	52	10.0	1	↓	↓			17		4	30	3													
223	1		75	52	10.0	1	↓	↓			17		5	1	4													
227	3		78	31	10.1	2	↓	↓			7		5	1	4													
233	5		78	56	10.0	4	↓	↓			17		6	12	2	121.8	6	12	5									
235	5		78	39	10.0	4	↓	↓			7		5	1	4													
237	6		77	72	10.2	2	↓	↓			17		5	1	4													
248	2		78	18	10.0		↓	↓			7		4	30	3													
301	3		↓	35	9.6		↓	↓			7	22	6	22	5													
354	3		↓	38	10.0		↓	↓			7	7	5	1	4													
354	3		↓	38	10.0		↓	↓			17		6	12	2													
a 358	2		↓	19	10.1		↓	↓			86		5	30	6					8		>50		8		>100		5/29
358	2		↓	19	10.1		↓	↓			28		6	11	2	38.8	6	11	3.3									
365	6		77	56	10.0		↓	↓			4		5	1	4													
367	6		78	57			↓	↓			10	17	6	21	2													
367	6		78	57			↓	↓			22		5	2	6													

a Stationed downtown to clock emissions

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: P-1-A through D

CITY:

TYPE OF VEHICLE : POLICE

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage	Mileage Since Tune-Up	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	B	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
114	←	NOT INSPECTED							→																			
217	↓		↓	↓	↓	↓	↓	↓			4		6	11	2	5.9	6	11	0.2									
152											17		6	11	2													
247											22		6	13	2													
247																0.8	6	13	3.6									
334											17		6	13	2													
310											17		6	13	2													
254											17		6	11	2	29.9	6	11	1.6									
458											22		6	13	2	58.9	6	11	2.1									
231											17		6	12	2	13.1	6	12	4.8									
307											7		6	12	2	4.4	6	12	2.9									
213											17		6	12	2	18.4	6	12	0.2									
406											17		6	12	2	9.9	6	12	0.7									
447											7		6	12	2													
65											17		6	12	2													
442											7		6	12	2													
											4		6	12	2													

SUMMARY OF DATA FROM VEHICLE INSPECTIONS AND STAIN TUBE, PERSONAL SAMPLER, AND CONTINUOUS ANALYZER CO MEASUREMENTS

FLEET: P-2-A & B CITY: ______ TYPE OF VEHICLE : POLICE

Veh. I.D. No.	Make of Vehicle	No. of Passengers	Year	Mileage in 1000s	Mileage Since Tune-Up 1000s	Tail-pipe Loc.	Tail-pipe Cond.	Intrusion Pts			Stain Tube CO		Stain Tube Date		Ave. Amb CO(ppm) on Stain Tube Date	Personal Sampler CO(ppm)	Personal Sampler Date		Ave Amb. CO(ppm) on Pers. Samp Date	Continuous CO Analyzer (ppm)								Type of Route
																				Interior				Exterior				
								A	B	C	F	R	Mo	Day			Mo	Day		Ave	Loc	Peak	Loc	Ave.	Loc	Peak	Loc	
266	1		78	12	12	2	0	0			← UNRELIABLE DATA →		4	12	1.0													
469	1		78	6.6	6.6	2	0	0					4	12	1.0					5		15		5		25		4/12
408	1		77	46.7	7.8	2	0	0					4	12	1.0					7		17		7		23		4/12
28	1		75	99.4	10	2	0	0					4	12	1.0													
12	1		76	14	1.0	1	0	0					4	13	1.0					3		7						4/12
122	1		76	72	10.0	1	0	0					4	13	1.0													
332	1		77	52	11.0	1	0	0					4	13	1.0													
182	1		77	25	10		0	0																				
331	1		77	79	10		0	0												5		25		8		46		5/15
308	1		78	6.8	6.8		0	0												10		30		5		>50		5/15
332	1		77	55.5	10.0		0	0												12		>50		8		>50		5/16
140	1		76	60.9	7.0		0	0												2		17		3		30		5/17
326	1		76	91.0	9.0		0	0												11		>50		8		>50		5/18
308	1		78	6.8	6.8		0	0												8		>50		5		>50		5/17

*U.S. GOVERNMENT PRINTING OFFICE: 1983/659-095/1917